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Health Promotion in Relation to Behavioral Nutrition and Physical Activity in the Era of Sars-Cov2 Pandemic

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Message from the Guest Editors

In the context of contemporary society, the condition generated by the Sars-Cov2 virus has created a megatrend on a planetary scale that has changed greatly the quality of daily life of its population with the first event in the history of humanity that can be considered as a *total social fact*. In addition, the crisis caused by COVID-19 and the lack of an organic vision has demonstrated the importance of a public health system that can respond to the complexity of its surrounding environment. Such complex needs make it necessary to provide complex and immediate answers. We have been able to record problems related to 'secondary causes of COVID' such as changes in eating habits, sedentariness, or the interruption of sports and motor activities. The 'secondary causes' identified here are to be interpreted as the possibility of increasing one's exposure to the risk of damage caused by the 'imperfect storm' of the pandemic. Therefore, it is necessary to change harmful attitudes in both individual and public health in order to achieve the goal of a complete state of well-being and not just the absence of disease, which is in accordance with the UN Agenda 2030 and the 17 SDGs.

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Message from the Editor-in-Chief

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Article

Home-Based Frailty Prevention Program for Older Women Participants of Kayoi-No-Ba during the COVID-19 Pandemic: A Feasibility Study

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Abstract: This study presents a single-arm intervention that aimed to determine the feasibility of a three-month home-based exercise program to prevent the progression of frailty during COVID-19. We recruited four groups of Kayoi-no-ba, or community salons for frailty prevention, and a total of 69 community-dwelling older women who belonged to one of the Kayoi-no-ba in a preliminary study for a follow-up study. The intervention program was developed on the basis of the 5A approach, and the focus group by the volunteer leaders of Kayoi-no-ba. We adapted the National Center for Geriatrics and Gerontology Home Exercise Program for Older People for 10-min daily home-based exercise. For feasibility outcomes, 91.3% of the participants completed the intervention program, whereas the percentage of exercise performed was 86.5% during the intervention period. For health-related outcomes, the five times sit-to-stand test exhibited significant improvement after the intervention. The results of feasibility outcomes indicate that the program may be feasible due to the high rates of completion and exercise performed. Additionally, improvement was noted for the health indicators of the five times sit-to-stand test, which may help prevent frailty. The feasibility trial has provided the necessary data to design a future-cluster randomized controlled trial.

Keywords: resistance training; five times sit-to-stand test; National Center for Geriatrics and Gerontology Home Exercise Program for Older People; home-based exercise

1. Introduction

Kayoi-no-ba has been attracting attention as a means of preventing the onset and progression of frailty among community-dwelling older adults in Japan [1]. The term Kayoi-no-ba broadly refers to activities focused on resident-centered frailty prevention

through physical exercise, hobbies, or other activities [2]. Moreover, it refers to places where older adults can interact with their neighbors regularly. In addition, Kayoi-no-ba is operated mainly by volunteer leaders with the financial support of the local government. However, the COVID-19 pandemic [3], which broke out in Wuhan, China in December 2019, forced many Kayoi-no-ba to be closed [4]. Previous studies have disclosed that community-dwelling older adults gained less opportunities to interact with others and less physical activity [5], such that concerns have emerged about the increased risk of frailty [6]. Alternatively, scholars have demonstrated in a randomized control trial (RCT) that a home-based exercise program implemented during the isolation imposed by COVID-19 led to the improvement of muscle strength in the lower limb [7]. Thus, the need exists to promote exercise programs that older adults can perform at home.

In May 2020, the National Center for Geriatrics and Gerontology published an information booklet entitled "National Center for Geriatrics and Gerontology Home Exercise Program for Older People (NCGG-HEPOP) 2020" to promote the prevention of frailty affected by restrictions on outings due to COVID-19. The booklet describes precautions in daily life and exercise methods, including resistance training and stretching exercises, which can be performed at home with the objective of maintaining mental and physical functions during the COVID-19 pandemic [8,9]. A meta-analysis of 25 intervention trials revealed that resistance training improved physical function, including grip strength, lower limb strength, and walking speed, among pre-frail, frail, and sarcopenic individuals [10]. In addition, a systematic review of intervention studies demonstrated that the effectiveness of exercise programs for pre-frail and frail individuals revealed high levels of improvement in frailty when conducted in groups [11].

Therefore, the researchers are convinced that providing intervention for the group of Kayoi-no-ba to maintain connection with peers for frailty prevention is important. We developed a frailty prevention program adapting the NCGG-HEPOP for the participants of Kayoi-no-ba. As the framework of the intervention program, we adopted the 5A approach, which is composed of five stages; i.e., Ask, Advise, Agree, Assist, and Arrange, and partially originates from the 4A (ask, advise, assist, and arrange) developed by the National Cancer Institute for smoking cessation treatment [12]. It is currently being applied to promote behavioral change and improve lifestyle habits in patients with chronic diseases such as obesity and diabetes [13]. To explore the possible barriers and promoters of the intervention, a focus group was conducted inviting nine volunteer leaders who manage the Kayoi-no-ba, as well as two public health nurses. According to the thematic analysis of the focus group under the framework of the 5A approach, the study extracted the following elements as the core of the intervention program: Ask: assessment of the current status; Advise and Agree: setting goals and approvement from leaders; Assist: recording exercise performance and sharing it within the group; and Arrange: follow-up from leaders by weekly phone call and support from specialists [14].

This study aims to determine the feasibility of a frailty prevention program based on Kayoi-no-ba. We are planning a cluster RCT study to verify the effectiveness of the program after this preliminary study.

2. Materials and Methods

2.1. Study Design

This is a feasibility study with one arm intervention. Feasibility studies have the ability to test the methodology of intervention studies that are planned to be conducted subsequently [15]. We planned this preliminary study to examine the feasibility of the program which we had newly developed, and to collect basic data and identify the barriers to conducting a cluster RCT. The study protocol was registered under UMIN-CTR (R000049753).

2.2. Participants and Setting

This study was conducted at the Kayoi-no-ba in Handa City, Aichi, Japan, where seniors in the community can gather and interact. Kayoi-no-ba meetings are held two to four times per month for the disability prevention program, which consists of exercise, brain training, and recreation. Leaders in each Kayoi-no-ba manage and facilitate the program content. The inclusion criteria were older adults who are registered and enrolled in the Kayoi-no-ba invited by the public health nurses. In September 2020, public health nurses invited the leaders of four Kayoi-no-ba to participate in a preliminary study. A total of 78 community-dwelling older adults belonging to one of the four Kayoi-no-ba were recruited for the current intervention. The exclusion criteria were (1) those without research consent, (2) those with declined cognitive function and considered unable to complete the program, (3) those with high risk of falling due to a decline in physical function, and (4) men. The reason why men were excluded is that there were only a few men among the Kayoi-no-ba participants, and the results could not be fully significant.

2.3. Intervention

The participants were instructed to perform 10 min of a home-based exercise program every day for three months. Table 1 presents a summary of the intervention program. First, the participants are tasked to read the NCGG-HEPOP booklets, which describe exercise methods distributed by the leader, and select an exercise program based on the flowcharts. This flowchart was established with reference to the questionnaires that have been reported to have validity in predicting the incidence of disability and death [8,16–19]. The results of this flowchart determined the most suitable exercise programs [2,8]. The original HEPOP includes a cogni-pack and a nutrition improvement pack, which the study did not use, as we focused on the physical exercise program [14].

Table 1. Overview of the intervention program.

	Performed by Leader	Performed by Participants
Content	• Distribution of NCGG-HEPOP booklet. • Distribution of exercise menu for 1 session for 10 min. • Check the participant's exercise record sheet on the day of the visit. • Check once a week about the status of the participant's exercise.	• Read the NCGG-HEPOP booklet. • Choose an exercise program based on the flow chart. • Perform 10 min of daily exercise at home • Describe goals, daily exercise records, and special notes in exercise record sheet • Submit the exercise record sheet to the leader on the day of the Kayoi-no-ba meeting.

In the next step, the leader distributed a printed sheet describing the selected exercise program [20] to each participant. Each exercise menu contained stretching and resistance training and can be completed in 10 min [20]. Details of the exercises are shown in Table 2. An intensity of 8–12 Repetition Maximum is recommended for resistance exercise to increase muscular strength, mass, and endurance [21]. Meanwhile, beginners performing high intensity training can cause pain [22] and decrease exercise adherence [23]. In addition, it is known that muscle strengthening can be obtained even with low intensity exercises [24], so the amount of load used in NCGG-HEPOP is based on an intensity that a typical older person would perceive as around 4 on the modified Borg scale [25]. In addition, a QR code was attached to the form so that the video could be viewed from there. The participants were expected to perform the 10-min daily exercise at home according to the exercise menu and were requested to write down their goals of the month on the form and mark the calendar if they conducted the exercise per day. The participants were asked to submit the exercise record sheet to the leader on the day of the Kayoi-no-ba meeting. Moreover, the leaders are expected to encourage the participants to continue the exercise and check the

exercise record sheet once per week. The leader contacted the participants via phone or e-mail if they were absent from the Kayoi-no-ba meeting or on a week when no Kayoi-no-ba meeting was held. In addition, the research office answered questions from leaders as required and provided support.

Table 2. Description of exercise content for each package of the NCGG-HEPOP.

Package	Exercise Type	Number of Sets	Number of Repetitions/ Implementation Time	Load
Strengthening package	Stretching the hamstrings	1	30 s each	-
	Stretching tight calf muscles	1	20 s each	-
	Squats	1	30 times	Body weight
	Standing training in a tandem position	1	30 s each	-
	Standing on one leg	1	30 s each	Body weight
	Marching in place	2	1 min	Body weight
Balance improvement package	Stretching the upper back and chest	3	10 s	-
	Stretching the arms and back	3	10 s	-
	Knee straightening exercise	2	10 times each	Body weight
	Standing heel raises	1	30 times	Body weight
	Standing up from a chair	1	30 times	Body weight
Inactivity prevention package	Stretching the quadriceps and front of the hip	1	30 s each	-
	Full body stretch	2	30 s	-
	Hip abduction exercise	3	20 times each	Body weight
	Twist exercise	3	10 times each	Body weight
	Drawing circles with the feet	2	10 times each	Body weight
	Standing heel raises	2	20 times	Body weight

Which package to implement was selected based on the flowchart. It was recommended that the relevant package be implemented once a day.

2.4. Outcomes

2.4.1. Feasibility Outcomes

The feasibility outcomes were retention rate, percentage of leaders and participants undergoing intervention, satisfaction of the participants, facilitation, and barriers to intervention. These data were collected during and at the end of the intervention.

Retention rate was defined as the percentage of the number of participants who continued until the end of the intervention from the number of enrolled participants. The percentage of leaders that implemented the intervention was calculated as the number of the recorded sheets of the participants confirmed by the leaders out of the expected number during the intervention period. The percentage of participants that underwent the intervention was calculated as the dates when the participants performed the exercise for the entire duration of the intervention period confirmed by the recorded sheets. The level of satisfaction of the participants was assessed using a five-point Likert-type scale at the end of the intervention. In addition, volunteer leaders were also interviewed after the intervention to determine the factors that facilitate and barriers to participation in the intervention.

2.4.2. Effectiveness Outcomes

Effectiveness outcomes were changes in the prevalence of frailty, health-related quality of life, changes in self-reported frequency of exercise, physical function, and physical activity. These data were collected before, during, and after the intervention.

The prevalence of frailty was determined using the score of the well-validated self-reported questionnaire called the Kihon Checklist, which is a 25-item with two Yes/No options, a Comprehensive Geriatric Assessment that evaluates the functions of older people [16]; scores of 0–3, 4–7, and 8 were designated as robust, pre-frail, and frail, respectively [26]. This indicator has been associated with the criteria of the Cardiovascular Health Study [27]; the sensitivity and specificity for frailty were reported to be 89.5% and 78.3%, respectively, and for pre-frailty were 70.3% and 80.7%, respectively [26]. In addition, its predictive validity for the incidence of disability and deaths in community-dwelling older adults three years later has also been confirmed [18]. The index of the risk assessment scale was calculated by extracting ten important indicators from the Kihon Checklist and assigning a score to each indicator to obtain the total score. This set of indicators has been validated in terms of predicting the incidence of disability within three years for community-dwelling older people [28].

For the assessment of the health-related quality of life, we used the EuroQol-5D-5L (EQ-5D-5L). The index consists of five dimensions (i.e., mobility, self-care, usual activities, pain/discomfort, and anxiety/depression), where each dimension is rated as no problems, slight problems, moderate problems, severe problems, and extreme problems. The values in this study were calculated using the conversion formula for the Japanese population [29], where death takes a value of 0, whereas perfect health takes a value of 1.

The change in exercise frequency was confirmed at the end of the intervention using a questionnaire adapted and modified from the questionnaire of the Japan Sports Promotion Center for comparison among community-dwelling older adults [30].

To evaluate physical function, the study measured grip strength and the five times sit-to-stand test as indicators of muscle strength measurements before and after the intervention. Grip strength was measured using a Smedley grip strength meter (T.K.K. 5001, Takei Scientific Instruments). The width of the dynamometer was set at the participant's second interphalangeal joint, with a stationary standing position with legs naturally open and arms hanging down beside the body [31]. Considering the burden on the subject, the number of measurements was one on each side. The test-retest reliability was maintained even with only one measurement [32]. The maximum value of grip strength was used [33]. The five times sit-to-stand test was measured by repeating five consecutive standing and sitting movements from a chair sitting position as quickly as possible. The study measured the time required from the start of the movement to the full standing position after the completion of the five standing movements [34]. A professional member of staff conducted both evaluations. For the five times sit-to-stand test, the measurement was conducted in two out of four Kayoi-no-ba.

Physical activity was adopted as the duration of activities from the moderate-vigorous physical activity (MVPA), which was 3.0 METs or more [35]. For the measurement, the study used a tri-axial accelerometer (Active style Pro HJA-750C, OMRON Healthcare) with an epoch length set to 60 s, taken before the intervention and at week 8 ($\pm$1 week) after the start of the intervention. During this period, the participants were instructed to wear the device from waking to bedtime across seven days. For inclusion in the analysis, participants wore the accelerometer for at least four days and for at least 10 h/day of valid wear time. The definition of non-wearing time is the total time that the activity intensity is below the detection threshold, whereas activity is considered to be 60 min or more of continuous zeros [36].

2.5. Sample Size

The main purpose of this study was to determine the feasibility of this program. For this reason, no sample size calculations were performed. The number of participants is within the range of a previous feasibility study [37].

2.6. Statistical Analysis

The feasibility outcomes were validated using descriptive statistics. For effectiveness outcomes, comparative tests were performed before and after the intervention. Based on the results of the Shapiro–Wilk test, a paired *t*-test and Wilcoxon rank-sum test were conducted, and for categorical variables the McNemar test was conducted. To investigate whether the health status of the participants affected the outcome, the participants were stratified using robust pre-frail/frail. All statistical analyses were performed using IBM SPSS Statistics 27.0 (IBM Corporation, Armonk, NY, USA), with $p < 0.05$ and $p < 0.10$ indicating the statistical significance and the statistical significance trend, respectively.

3. Results

We recruited four groups of Kayoi-no-ba with a total of 78 community-dwelling older adults attending the information sessions. Nine were excluded due to the lack of consent ($n = 1$), cognitive impairment ($n = 4$) and men ($n = 4$) which resulted in 69 participants. During the intervention period, six participants dropped out due to health problems, whereas 63 (91.3%) completed the program. No participant pointed to a difficulty in participating in this program due to the content of the intervention.

Table 3 presents the baseline characteristics of the participants. The mean age was 79.5 ± 5.3 years; 39.7% were robust, whereas 60.3% were pre-frail or frail.

Table 3. Characteristics of the participants at baseline.

	All (n = 63)		**Robust (n = 25)**		**Pre-Frail and Frail (n = 38)**	
Age (mean/SD)	79.5	5.3	78.2	4.1	80.3	5.7
Body mass index (n/%)						
<18.5	5	7.9	2	8.0	3	7.9
18.5–24.9	51	81.0	21	84.0	30	78.9
≥25.0	7	11.1	2	8.0	5	13.2
Disease status (multiple answers) (n/%)						
Stroke	2	3.2	1	4.0	1	2.6
Cardiovascular disease	11	17.5	6	25.0	5	13.2
Diabetes mellitus	5	7.9	3	12.5	2	5.3
Respiratory disease	7	11.1	2	8.3	5	13.2
Musculoskeletal disorders	6	9.5	1	4.2	5	11.9
Number of medications (n/%)						
None	8	12.7	2	8.0	6	15.8
One or two	21	33.3	12	48.0	9	23.7
Three or four	25	39.7	6	24.0	19	50.0
Five or more	8	12.7	4	16.0	4	10.5

SD: standard deviation.

Table 4 illustrates the results of the intervention. The percentage of participants that completed the intervention was 86.5 ± 20.0% and 74.6 ± 21.7% for the leaders on average. The percentage of satisfied participants was 58.7%. When comparing the robust and pre-frail/frail participants, the percentage of implementation was higher for the robust group.

Table 4. Feasibility outcomes during the intervention and at the end of the intervention.

		All (n = 63)		Robust (n = 25)		Pre-Frail and Frail (n = 38)	
Date during the intervention period							
Percentage of leaders confirming implementation (mean/SD)		74.6	21.7	79.3	16.1	71.5	24.4
Percentage of exercise performed (mean/SD)		86.5	20.0	91.1	14.2	83.5	22.7
Data at the end of the intervention							
Satisfaction (n/%)	Extremely satisfied	21	33.3	11	45.8	10	26.3
	Satisfied	16	25.4	5	20.8	11	28.9
	Neutral	22	34.9	8	33.3	14	36.8
	Unsatisfied	2	3.2	0	0.0	2	5.3
	Extremely unsatisfied	0	0.0	0	0.0	0	0.0
	Missing	2	3.2	1	4.2	1	2.6

SD: standard deviation.

Based on the interviews with the leaders, the study identified the facilitating and barrier factors of the intervention as follows. The use of the record sheet was a facilitating factor in maintaining the motivation of the participants to continue the exercise. In addition, the motivation of the participants could be encouraged by the improvement in physical function and by participating with their group members. As a barrier factor, several leaders complained that individually calling the participants to check their performance was a stress. However, they felt rewarded by becoming acquainted with aspects of the participants through phone calls. Additionally, some participants exercised using their personal methods, because they lacked access to the video through the QR code. Moreover, the leaders recognized that the participants performed the exercise much more positively than they had expected.

Table 5 presents a comparison between before and after the intervention of the health indicators and changes in exercise frequency. In summary, the five times sit-to-stand test indicated a significant improvement, whereas grip strength exhibited a significant trend toward improvement for robustness. In addition, a significant improvement was observed using the risk assessment scale among the pre-frailty/frailty groups. Alternatively, the EQ-5D-5L produced worse results for robustness. The amount of physical activity assessed by the accelerometer remained the same. Approximately half of the participants reported an increase in the frequency of exercise after the intervention.

Table 5. Changes in health indicators before and after the intervention.

		All (*n* = 63)						Robust (*n* = 25)						Pre-Frail and Frail (*n* = 38)					
		n	Pre		Post		*p*	*n*	Pre		Post		*p*	*n*	Pre		Post		*p*
Frail	*n*/%	61	18	29.5	14	23.0	0.289	24	0	0.0	0	0.0	-	37	18	48.6	14	37.8	0.289
Risk assessment scale	Mean/SD	57	21.2	7.0	20.7	6.8	0.248	24	17.4	5.4	17.9	4.7	0.357	33	23.9	6.7	22.7	7.5	0.048
EQ5D5L	Median (25–75)	61	0.895	0.823–1.000	0.895	0.780–0.895	0.099	23	0.895	0.895–1.000	0.895	0.871–0.895	0.029	38	0.831	0.759–0.895	0.837	0.729–0.895	0.399
Grip strength (kg)	Mean/SD	59	22.3	4.1	22.8	4.4	0.106	25	21.5	4.7	22.4	4.5	0.091	34	22.9	3.5	23.1	4.4	0.669
Five times sit-to-stand test (seconds)	Median (25–75)	38	9.9	8.4–11.7	8.2	7.3–9.6	<0.001	19	9.1	7.7–10.8	7.8	7.0–9.5	0.001	19	11.4	9.2–13.6	9.1	7.9–10.1	0.001
MVPA (min/day)	Median (25–75)	51	31.7	15.4–49.9	28.3	15.4–42.7	0.484	22	37.7	26.6–52.5	33.6	22.9–60.4	0.758	29	23.6	8.1–44.6	20.4	14.4–38.5	0.452
Change in frequency of exercise (*n*/%)																			
	Increased	63			30	47.6					14	56.0					16	42.1	
	Slight/no change				31	49.2					10	40.0					21	55.3	
	Decreased				0	0.0					0	0.0					0	0.0	
	Missing				2	3.2					1	4.0					1	2.6	

MVPA; moderate to vigorous physical activity. Post-evaluation of MVPA was measured at 8 (±1) weeks after the start of the intervention. Changes in frequency of exercise are assessed at the end of the intervention and do not represent pre-intervention results.

4. Discussion

This study examined the feasibility of the three-month home-based exercise program in preventing the progression of frailty. We confirmed high retention rates and a high percentage for implementing the intervention, which indicate feasibility. Physical function evaluated for potential effectiveness also improved, whereas the frequency of exercise increased. For the next cluster RCT, the following points can be noted: adapting the exercise intensity for each participant, providing clear instructions for the exercise, promoting an exercise program for frail participants who are unable to maintain exercise, and lessening the burden of leaders in monitoring the participants once a week. These pointers were considered to be within the range of possible improvements.

A previous study that assessed community-dwelling older adults for frailty using the Kihon Checklist shows that 17.2% were frail [18], compared to 29.5% in the present study. In a study of the Kayoi-no-ba, the percentage of those aged 75 or older was reported to be 37.0–59.5% [38,39], and 82.5% participants in this study were older. The current study participants are older than in previous studies and have a higher prevalence of frailty.

A systematic review of intervention studies of home-based resistance training reported an average continuation rate of 85.0% and an average overall compliance (% completed workouts) rate of 69.5% [40], with a continuation rate of 91.3% and an exercise compliance rate of 86.5%, which are higher than those of the current study. Compared with the 100% satisfaction of the respondents in the health education study for the prevention of care for community-dwelling older adults [41], the percentage of satisfied respondents in this study (58.7%) was low. Alternatively, the number of dissatisfied respondents was extremely low (3.2%). Those who did not respond "satisfied" tended to be older, frail, and with low percentages of exercise performed. More detailed support is needed for those with higher age and frailty at the baseline assessment to help them achieve a satisfaction through the home-based program. In terms of the change in exercise frequency, a survey conducted by the Sports Agency in 2019 prior to the COVID-19 pandemic indicated that 15.3–16.4% of the respondents aged 60–70 years women reported an increase, whereas 17.3–17.8% reported a decrease when asked about the change in their exercise frequency compared to the previous year [30]. In the post-intervention survey of the current study, exercise frequency increased in 47.6% of the participants, and did not decrease, which suggests that the current intervention increased exercise frequency.

In the interviews after the intervention, the comments from the leaders were generally positive. A few felt that weekly phone calls were a burden, but found that strengthening the connection of the group is a worthy effort. Limiting phone calls only to the beginning of the program may reduce the stress of leaders and improve implementation in future dissemination, despite the currently high rate (74.6%).

The retention rate and percentage of exercise performed to evaluate the feasibility of the current study were better than those of previous research. A systematic review that assessed the factors associated with participation in resistance training has suggested four key points for promoting resistance training [23]; i.e., (1) targeting people with health problems, (2) providing enjoyment and helping to build self-efficacy, (3) obtaining support from others, and (4) planning and self-monitoring [23]. The current program contains these four key points, which enabled the achievement of high feasibility. However, contrary to our expectation, the percentage of the exercise performed was lower among the pre-frail/frail group than the robust participants. Thus, they may need extensive support to promote self-efficacy, with encouragement from leaders to participate.

The present study observed a significant improvement in the physical function assessed using the five times sit-to-stand test. This result is consistent with a meta-analysis that reported improvements in physical function, including grip strength and the five times sit-to-stand test by resistance training among pre-frail/frail individuals [10]. In addition, the risk assessment scale demonstrated an improvement among the pre-frail/frail participants. The scale is an early indicator of disability [28], and this intervention may be able to delay disability. The EQ5D5L unexpectedly tended to worsen among the robust sub-group.

The mean value of Japanese women aged 70 years or older in the EQ5D5L was reported at 0.828 ± 0.202 [42], whereas the mean EQ5D5L for robustness in the current study was 0.936 ± 0.059 and 0.900 ± 0.062 before and after the intervention, respectively. Both values are higher than the average of the general population. Thus, regression to the mean [43] may be the reason underlying this result. As such, verifying the effect in the next cluster of RCT is necessary.

Although the percentage of the performed exercise was high, improvement in the physical activity quantity was not observed, unexpectedly. According to the interview results, the participants exercised using their personal style, because they were unable to watch the video. Therefore, a possibility exists that changes in the amount of physical activity assessed using the MVPA could not be captured, because the participants performed exercises with insufficient intensity. In the next cluster RCT, improving the method of the environmental setting of the video is necessary to improve the quality of the exercise method and to confirm the exercise method by experts.

The strength of this study is that we showed the feasibility of the home-based exercise program while maintaining a connection with peers in the midst of COVID-19. However, the current study also includes the following limitations. First, the study did not set a target value in advance of proceeding with the cluster RCT. However, the retention rate and percentage of the performed exercise, which formed the feasibility index, were considerably high. Therefore, the study infers that the current program was acceptable. Second, this study is a feasibility study with one arm intervention. Therefore, it is not sufficient to objectively evaluate effectiveness. We are planning the cluster RCT to determine effectiveness of this program. Third, there are issues regarding the generalizability of the results of this study. As the participants of this study are limited to women in a city, it is not possible to discuss the applicability of this study to other regions or men. However, more than 80% of those attending the Kayoi-no-ba are women [38,39], which could be applied to many Kayoi-no-ba. In addition, the program was developed on the basis of the focus group held, whereas a few leaders of the Kayoi-no-ba were invited. The experience of co-development of the program through the focus group may render the leaders more proactive in their approach to the participants. As such, this process may have undermined the generalizability of the program.

5. Conclusions

The study confirmed the high retention rate and the high percentage of exercise performed, whereas the low level of burden felt by the leader indicated that the study is feasible. A trend was observed toward improvement in health indicators, which may help prevent the progression of frailty. However, the effectiveness of the intervention remains unknown due to the lack of detection power and the comparison of one arm. In the future, on the basis of the correction of the points of improvement obtained in the current study, conducting a cluster RCT with power to confirm the effectiveness is necessary.

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Informed Consent Statement: Informed consent was obtained from all participants.

Data Availability Statement: An anonymous analyzed data will be available to researchers upon reasonable request to the corresponding author.

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Changes in Physical Activity Levels and Eating Behaviours during the COVID-19 Pandemic: Sociodemographic Analysis in University Students

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Abstract: The COVID-19 pandemic has forced schools and universities to shift their activities online, influencing the adoption of health-related behaviours such as physical activity and healthy dietary habits. The present study investigates the changes in adherence to a healthy diet and regular physical activity in university students in Italy before and during the COVID-19 pandemic and understands the role of sociodemographic variables in creating the changes above. We conducted a repeated cross-sectional survey performing the same sampling strategy at the first data collection (T0) and second data collection (T1) with a combination of convenience and snowball sampling approaches. The sample is composed of a total of 2001 students, 60.2% women and 39.8% men, with an average age of 22.7 (±5.5 SD). At T1, 39.9% of the students reported regular physical activity. During the pandemic, however, many, especially male students, abandoned or reduced physical activity practice (T1 40%), with an increase in social media use (T0 52.1%; T1 90%). A direct association between very low frequency of physical activity and increased sedentary time (r = 0.2, p = 0.001) and between change in dietary style and increased Body Mass Index (BMI) value (r = 0.3, p = 0.002) was found. The multivariate analysis for the total sample showed that some sociodemographic variables such as gender, age, parents' level of education, area of study, household type, and perception of one's body influence eating behaviours and physical activity. Our findings suggest that universities should invest in the protection and promotion of the health of their students with specific awareness programmes, and further research should repeat the survey in the post-lockdown period to investigate the long-term effects on health-related behaviours.

Keywords: healthy lifestyle; young adults; COVID-19; physical activity; exercise; sedentary behaviour; diet; eating habits; university students

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1. Introduction

Modifiable risk factors related to unhealthy behaviours and lifestyles, such as tobacco use, unhealthy diet, lack of physical activity (PA), and alcohol abuse, among others, are associated with many chronic conditions and with an onset of non-communicable diseases (NCDs) causing the majority of deaths worldwide, regardless of age, sex or geographic origin [1–3]. Around 75% of premature deaths caused by NCDs occur in adults aged 30–69 years, demonstrating that NCDs are not only a problem for older people [3–5].

The majority of risky behaviours are indeed established at an early age and are consolidated in adulthood. During adolescence, youth begin to develop habits that will carry over into adulthood with considerable repercussions on their risk for NCDs [4,6]. Therefore, adolescents and young adults represent the most important target for preventive intervention of NCDs. The transition from high school to university is also a critical stage in the development of health-related behavioural habits, and previous studies found that in this phase of their life, university students are prone to adopt unhealthier behaviours [7–9].

Compliance with a healthy lifestyle, especially the adherence to a combination of more than one healthy behaviour, is associated with a lower risk of mortality and a reduced risk of NCDs [5,10–13]. The most effective measure available to tackle NCDs is, therefore, their prevention at all stages of life, which represents a significant public health challenge worldwide.

An unhealthy diet and physical inactivity are among the most critical risk factors for NCDs. It has also been established that the combination of physical activity and healthy nutrition has the best health benefits and modulates health throughout the lifespan [14–16].

Physical inactivity represents the fourth most common risk factor for deaths worldwide, responsible for approximately 3.2 million deaths each year. Physically inactivity has been associated with an unfavourable cardiovascular disease risk profile, including obesity, insulin resistance, and high blood pressure [17,18].

To encourage this highly protective health behaviour, in 2018, the World Health Assembly (WHA) approved a new *Global Action Plan on Physical Activity (GAPPA) 2018–2030*. It adopted a new voluntary global target to reduce international levels of physical inactivity in adults and adolescents by 10% by 2025 and 15% by 2030 [19]. Nevertheless, one in four (27.5%) adults and more than three-quarters (81%) of adolescents worldwide do not practice enough PA [20], and this seems to be true also for university students who can exceed 9 h per day of sedentary time [21–23] and decrease the practice of physical activity [24–26].

In Italy, according to the National Institute of Statistics (ISTAT), in 2019, the percentage of sedentary people was 35.6%, and the practice of physical activities and sport decreased with age [27].

Unhealthy eating behaviours, excess body weight, excessive consumption of energy, saturated fats, trans fats, sugar, and salt, and low consumption of vegetables, fruits, and whole grains are also leading risk factors and significant public health concerns [28]. Food selections and dietary patterns such as skipping meals, under-eating, or over-eating can lead to a decrease in diet quality and increased risk of chronic diseases [29].

Starting from the beginning of 2020, the restrictive measures put in place by governments to limit the spread of the SARS-CoV2 virus worldwide and, more specifically in Italy, strongly affected PA and nutrition behaviours [30]. Changes in food consumption, type of food, number of meals and snacks, for example, and a decrease in time spent in physical activity and changes related to the type of activities were recorded during the pandemic [31].

In response to the rapid increase in the number of COVID-19 cases, the Italian government declared a state of emergency on 31 January 2020 [32] under Legislative Decree 1/2018 and on 9 March, Italy was the first European country to enter a nationwide lockdown, which was initially imposed on some northern Italian region, and within days, extended to throughout the country.

The Italian government, like many European countries, put in place unprecedented non-pharmacological community interventions to control and prevent the spread of the disease throughout the country with restrictions more and more severe: from the obligation for everyone to stay at home, banning mass gatherings and public events, closing schools and universities, retail stores, bars and restaurants, encouraging people to work from home and avoiding going out in public, to the limitation of free movement of people, including sport-related activities, walking and running outdoors, to the closure of almost all work activities [33–36].

All these measures influenced the perception of risk, the perception of individual self-efficacy, the value attributed to social responsibility and the trust in health authorities and others, and the adoption of certain health-related behaviours [37].

Most of the restrictive measures had limited the participation in physical activity, sport, and exercise with a resulting increase in sedentary behaviours and inactivity levels, which may lead to increased risk for physical and mental health problems [30,37–41].

University students who often use active commuting to reach the university for short and medium distances reduced their daily energy expenditure and increased the time spent sitting to listen to online classes and study from home [38].

To counteract inactivity and sedentary behaviours, experts recommend taking any chance to walk and stand up, do home-based physical activities and exercise, and try to be regular [42]. Playing active video games (AVGs) could also be a valuable strategy to reduce sedentary behaviours when it is not possible to do other physical activities outside of the house [43].

Italian studies on eating habits changes during the COVID-19 lockdown affirmed that the sense of hunger and satiety changed for more than half of the population with less appetite or increased appetite; an increase in the intake of sweets, salty snacks, sweet beverages, and alcohol was reported, as well an increase in the consumption of healthy foods, such as fruits and vegetables, extra virgin olive oil, and legumes [30,40,44–47]. A previous study conducted in Italy showed that, in university students, healthy food consumption and dietary habits during the COVID-19 pandemic were influenced mostly by the practice of exercise and by mental health, including mood states and self-efficacy [46].

Several studies have been conducted on the PA and nutrition of children and adolescents before and during the COVID-19 pandemic worldwide and also in Italy. Still, few researchers investigated the specific population of university students with data collected before and during the pandemic [38,40].

All these reasons have led us to carry out a study aimed at investigating eating behaviours and physical activity levels in university students in Italy before and during the COVID-19 pandemic and investigating whether these behaviours and any changes are influenced by sociodemographic and individual variables such as lifestyle before the pandemic.

Moreover, the findings of the present survey, by assessing the main modifiable risk factors for NCDs, dietary habits, and PA through the self-reported experience of university students, could be helpful in the development of preventive actions for this specific target population.

2. Materials and Methods

2.1. Design and Selection of Study Subjects

The sample size was selected at convenience without aprioristic statistical calculations and non-probabilistic random sampling.

We conducted a repeated cross-sectional survey by submitting the same questionnaire in two different periods, before and during the pandemic [48,49]. Students enrolled in bachelor's or master's programmes at universities in central Italy were invited to participate in the study through their student representatives and social media networks such as Facebook and WhatsApp platforms (Meta Platforms, Inc, Menlo Park, CA, USA). In order to recruit a large and diverse sample, no particular groups were targeted, and no exclusion criteria were specified; however, questionnaires that were incomplete or completed by students from universities located in a geographical area different from central Italy were excluded from the analysis.

Detailed information on the purpose of the study and the statement on anonymity were clearly described at the beginning of the questionnaire. Authorisation to process sensitive data (General Data Protection Regulation 2016/679) [50] and informed consent were mandatory fields to continue the survey.

The first data collection took place between November 2018 and February 2019 (T0). Students were asked to fill in a questionnaire in a paper format containing information on sociodemographic data and lifestyles (physical activity, eating habits, tobacco smoking, alcohol use and substance abuse, sexual behaviours). At T0, we collected data from 1025 students (35.5% men 64.5% women), with an average age of 22.6 years old (±3.6 SD).

The second data collection took place online, during the COVID-19 pandemic, between November 2020 and February 2021 (T1). At T1, we collected data from 976 students (31.3%

men, 68.7% women), with an average age of 21.3 years old (±4.1 SD). The questionnaire was uploaded on the Google Form platform, and the same sampling strategy was performed for the recruitment of T0 students. We used the same questionnaire as in the first data collection, but we decided to exclude questions about behaviours other than physical activity and eating habits and to add some questions about media and leisure time activities during the pandemic and the perceptions of change in PA and eating behaviours.

For the two data collections, the same sampling strategy was used with a combination of convenience and snowball sampling approaches. The availability of data before and during the pandemic and the use of the same survey instrument and two samples with very similar characteristics (socio-demographic, PA and eating habits) justified the sample size and selection and made the subsamples statistically comparable.

2.2. Survey Tool

The questionnaires were created ad hoc, in Italian, by the Health Education Observatory of the Hygiene Laboratory of the Department of Human Sciences, Society and Health of the University of Cassino and Southern Lazio. They included adapted questions on health behaviours from the Health Behaviour in School-aged Children (HBSC) survey [51]. The questionnaire was initially submitted to school-aged students and university students. Only the university students were included in the analysis for the present study.

The first version of the questionnaire consisted of 125 items, divided into six sections. The first section (I) gathered sociodemographic and family-related data (gender, age, area of residence, parents' level of education and occupation, family environment, etc.). It used categories defined by ISTAT [52]. Section two (II) included information about the use of drugs, followed by details regarding tobacco smoking habits and the consumption of alcoholic beverages (III and IV sections). Reproductive health and sexual behaviours were the main topics of the fifth (V) section, while section VI focused on physical activity and eating habits.

In this last section, students were asked to indicate if they performed any PA (yes/no), the frequency (days per week), and the type of PA and sport eventually practised. According to the yes/no answer about the PA practice, we created two categories, sedentary and active, and then, for active students, we made three subcategories of frequency, namely very low frequency (a few times a month–less than one time per week), low frequency (1–2 times per week), and medium-high frequency (three times per week or more).

Eating habits questions included the number of meals, the distribution of meals during the day (heavy/light meals), and the motivation to skip meals, if any.

Weight and height data were self-reported and used to calculate the Body Mass Index (BMI) and then to define the status of underweight, average weight, overweight, and obese using the International Obesity Task Force (IOTF) thresholds from Cole et al. (2012) [53]. In addition, one question was added to detect the students' self-perception of their weight status.

The descriptions of the health behaviours we were investigating were reported in the questionnaire according to the definitions used by the WHO and the international survey on the health, well-being, and behaviour of young people "Health Behaviour in School-aged Children" (HBSC) [54,55].

The second version of the questionnaire consisted of 49 items. Items 1–14 (sociodemographic and family-related questions) corresponded to section I of the previously described questionnaire. Items 15–20 investigated physical activity behaviours (type, frequency, motivation) with the same questions as the first version of the questionnaire. Information about eating habits (same questions as the first version) was requested in items 21–31, while the last part of the questionnaire investigated the use of media and leisure time during the pandemic (items 32–49). Questions about the perception of changes in PA and eating behaviours during the COVID-19 pandemic were added to this version of the questionnaire.

2.3. Statistical Analysis

A descriptive univariate analysis was performed to represent the dataset synthetically and to describe the sociodemographic and lifestyle characteristics of the two different samples using a simple frequency distribution. A bivariate analysis was performed to investigate the association between sociodemographic factors (gender, age, education level, and parental occupation) and lifestyle.

Exploratory analyses were used to investigate the distribution of the independent variables. Differences between groups were estimated using the Chi-square test and tests without distribution, and those with a p-value < 0.05 were considered significant. The values of Cronbach's alpha (coefficient of internal consistency) and the Mann–Whitney U test were used to determine the mean differences in the perceived change spent in physical activity of the student respondents in the two periods considered (indicated as T0 = before the pandemic and T1 = pandemic).

The calculation of Body Mass Index (BMI = kg/m^2) and the classification into underweight, average weight, overweight, and obese was carried out according to Cole's tables, separately for age and gender in both samples [53].

A simple linear regression model assessed the relationship between the dependent variables (sedentary lifestyle and change in BMI value) and the independent variables (physical activity, healthy eating behaviours).

The adjustment for sociodemographic characteristics (age, gender, area of study, parents' level of education, perception of one's body) took place through the coding of the sociodemographic variables that could influence the behaviour of our sample, and consequently, some dummy variables were created, and the possible effects of the changes on the dependent variables (PA and Eating Habits) were evaluated.

Appropriate logistic regression models were built to investigate the association between health behaviours adherence and eventual modification during the pandemic (attainment of recommended PA levels and commitment to a good eating pattern) about certain ascertained risk factors such as age (categorised as less than/equal to 25 years or more than 26 years), gender (male or female), perception of one's body (positive or negative); type of degree programme, including scientific (engineering, mathematics), humanities (humanities, philosophy, education, social work, exercise science) health (medicine, biology, biotechnology, nursing), business/legal; parental education levels categorised as low (≤elementary school), medium (middle school and high school), and high (≥college); and BMI (classified as usual and overweight).

The dependent variable for PA was built with two specific models: the first assigned a dichotomous YES/NO value, "YES" identifying participants who engaged in physical activity and "NO" those who did not engage in any physical activity (sedentary), the second assigned a value of 1 to those who reported engaging in physical activity with a very low frequency (<of 1 time per week), 2 to those with a low frequency (1–2 times per week), and 3 to those who engaged in physical activity with a medium-high frequency (three times per week or more).

The number of meals per day (1-2-3-4-5 or more) was considered for eating habits.

Risk factors were calculated by adjusting odds ratios (ORs) and 95% confidence intervals (CIs).

Statistical analyses were performed using the EpiInfo 3.5 statistical package; the statistical significance level was set at $p < 0.05$.

3. Results

One thousand twenty-five students at T0 and 976 at T1 from central Italy responded entirely to the questionnaire. The values of Cronbach's alpha (coefficient of internal consistency) for the questionnaire used in the study were 0.74 and 0.78, respectively, for the study carried out at T0 and T1. The values obtained showed a satisfactory level of reliability [56]. The total sample consisted mainly of women (60.2% women vs. 39.8% men), with a mean

age comparable between the groups. The sociodemographic characteristics of the two samples (T0 and T1) are shown in Table 1.

Table 1. Characteristics of the study population: total sample, sample at T0 and sample at T1.

	Total (*n*. 2001)	**T0 (*n*. 1025)**	**T1 (*n*. 976)**
Age (average)	22.7 years ± 5.5 SD	22.6 years ± 3.6 SD	21.3 years ± 4.1 SD
Gender (%)			
male	39.8	35.5	31.3
female	60.2	64.5	68.7
Fathter Educational level (%)			
no formal education	0.8	0.9	0.6
primary	19.0	16.8	19.9
secondary	41.3	42.6	40.6
university	38.9	39.7	39.9
Mother Educational level (%)			
no formal education	1.1	1.3	0.8
primary	15.2	16.2	15.5
secondary	41.3	39.4	40.0
university	42.4	43.1	43.7
Relationship Status (%)			
live with their family	59.2	54.2	82.9
live alone	29.7	36.4	12.8
other	11.1	9.4	4.3
Area of study (%)			
Scientific	16.9	18.1	17.1
Humanities	44.2	43.0	42.2
Health sciences	29.9	31.4	32.3
Legal/Business	9.0	7.9	8.4

The values of Cronbach's alpha (coefficient of internal consistency) for the questionnaire used in the study was 0.74 and 0.78, respectively, for the study carried out at T0 and T1.

Table 2 shows descriptive data about the statistically significant changes in the regular practice of PA, eating habits, BMI, and perception of one's weight status in the total sample and the two subsamples (T0 and T1).

Table 2. Statistically significant changes of physical activity, eating behaviours, BMI, and perception of own body weight by gender.

	Total (*n*. 2001)		**T0 (*n*. 1025)**		**T1 (*n*. 976)**	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**
Regular PA practice (%)						
Yes (1–2 times per week)	53.1	46.9	56.9	43.3	60.8	39.2
PA practice motivations (%)						
Lose weight	22.2	67.6	25.7	56.9	19.9	61.1
Daily meals frequency (%)						
5	11.1	15.7	10.3	14.4	31.3	40.0
3	59.9	40.4	58.7	47.8	59.0	57.2
2	30	29.2	31.0	32.3	7.0	5.9
Eating Breakfast (%)						
Rarely	59.8	39.7	50.3	33.7	62.8	42.9
Have been on a diet(%)						
at least once	8.2	76.9	9.1	74.4	7.7	71.1
BMI(%)						
Overweight	21.6	17.9	28.5	20.1	33.5	29.2
Obese	8.9	9.8	6.7	10.1	9.9	10.7
Perception of own weight status(%)						
Overweight	32.3	72.1	29.4	68.2	23.1	77.8

Statistically significant differences $p < 0.001$.

In this study, 39.9% of the total sample (2001) reported practising physical activity regularly before the pandemic; about 65% of them declared to practise with a frequency of three times a week. When analysing the most active segments of the examined population, some statistically significant differences emerged in sex and age in the two groups. Male students (T0 56. 9% vs. 43.3% of females; $p = 0.001$ vs. T1 60.8% vs. 39.2% of females; $p = 0.002$) and the youngest (T0 61.9% of those aged $\leq$25 years vs. 38.7% of those aged $\geq$26 years; $p = 0.03$ vs. T1 55.6% of those aged $\leq$25 years vs. 37.0% of those aged $\geq$26 years; $p = 0.03$) reported to practise at least one sport regularly. Analysing the frequency of the type of faculty, it emerges that, in the total sample (T0 + T1), those who declare to do physical activity regularly are mainly students enrolled in degree courses in exercise science and health disciplines (73.1% vs. 33.9% other courses; $p = 0.03$), and who live alone (67.2% vs. 39.6% in a family $p = 0.04$). The sports most practised are swimming, jogging, and gymnastics/fitness, and the motivations are to be healthy (T0 40.7%; T1 38.9%), to get rid of stress (T0 34%; T1 32.8%), and to lose weight (T0 26.9%; T1 21.1%), the latter a motivation declared mainly by the female respondents in both groups (67.6%; $p = 0.007$). With the advent of the pandemic, however, many abandoned this practice (T1 40%), with a relative increase in sedentariness and social media use (T0 52.1%; T1 90%) mainly among male respondents in both groups (61.5% vs. 31.8% female; $p = 0.002$). As expected (T1), the pandemic resulted in less time devoted to physical activity (<of 2 times per week, $p = 0.001$) and consequently more sedentary activity, especially in women. In fact, there was a direct association between very low frequency of physical activity and increased sedentary (r = 0.2, $p = 0.001$) and between change in dietary style and increased BMI value (r = 0.3, $p = 0.002$).

The mean weight and mean height of the total sample were within the normal mean values, with differences between the sexes, respectively Kg69.5 $\pm$ 15.1 male vs. Kg61.08 $\pm$ 10.6 female ($p = 0.000$) and cm184 $\pm$ 7.06 male vs. cm170 $\pm$ 5.7 female ($p = 0.000$). Weight assessment according to BMI (calculated from self-reported weight and height), reported underweight (T0 2.9% vs. T1 1.8%), normal weight (T0 85.7% vs. T1 81.6%), overweight (T0 9.9% vs. T1 14.3%) and obese (T0 1.5% vs. T1 2.3%), overall males were overweight and females obese (Table 2). The percentage of overweight students seemed to increase with increasing age, from 1.6% in the group of $\leq$25 years to 2.3% $\geq$ 26 years ($p = 0.03$).

The subjective perception of one's own weight status mirrors the objective data. In fact, the overall sample considers itself to be normal weight (65.4%), but with statistically significant differences between the two sexes in relation to overweight (Table 2) and between the different groups of the sample according to the temporal location of 64.4% T0 vs. 35.4% T1 ($p = 0.004$).

As an indicator of eating behaviour, we used the number of meals during the day. In the total sample, the frequency of meals is distributed as follows: 11.1% indicated having five meals, 59.9% had three meals, and 30% had two meals. These percentages vary in the two subgroups (T0 respectively 10.3%, 58.7%, and 31% versus T1 31.3%, 59%, and 7%). Breakfast is regularly eaten by more than 50% of young people before leaving home; this healthy habit decreases with increasing age (from 38.3% of the group $\leq$25 years to 23.2% of the group $\geq$26 years $p = 0.02$) and changes according to gender. Women seem to eat breakfast more rarely (Table 2), especially among respondents with working mothers ($p = 0.001$). This difference is more pronounced in the group $\leq$25 years (41.2%), while it is smaller in the group $\geq$26 years (29.1%) ($p = 0.02$). The morning snack is consumed by 31% of women and 18.1% of men. The majority of students consume the two main meals of the day, mainly at home with their families. Thirty-nine percent claim to have followed a diet at least once, and most women report this (Table 2). A total of 15.8% of young people at T0 report being on a diet at the time of the survey, which decreases by about five percentage points during the block (T1). Furthermore, the adoption of dieting increases with age and is predominantly practised by women (33.2%) compared to men (15.9%).

After adjustment for sociodemographic characteristics, the logistic regression models show that of the total sample participants being male, being older than 26 years, living in households with both parents with a low level of education, and having a positive body perception are risk factors for adopting a sedentary lifestyle, risk factors confirmed by applying the same regression models to the two subsamples compared at T0 and T1 (Table 3).

Table 3. Logistic regression models relating some sociodemographic variables and PA in the total sample and the two subsamples (T0 and T1).

		Physical Actvity (PA)	
		OR	**95% CI**
TOTAL SAMPLE (*n*. 2001)			
Gender	Female	1	
	Male	1.49	1.12–2.58
Age	≤25	1	
	≥26	1.52	1.29–2.72
Living with parents with a low level of education	No	1	
	Yes	1.36	1.15–1.88
Have a positive body perception	No	1	
	Yes	4.2	2.10–6.90
T0 (*n*. 1025)			
Gender	Female	1	
	Male	1.31	1.17–1.97
Age	≤25	1	
	≥26	1.39	1.08–1.78
Living with parents with a low level of education	No	1	
	Yes	1.85	1.05–3.25
Have a positive body perception	No	1	
	Yes	2.61	1.91–4.98
T1 (*n*. 976)			
Gender	Female	1	
	Male	1.61	1.32–1.96
Age	≤25	1	
	≥26	1.36	1.04–2.71
Living with parents with a low level of education	No	1	
	Yes	1.57	1.07–3.48
Have a positive body perception	No	1	
	Yes	2.18	1.89–3.51

Statistically significant differences $p < 0.001$.

In contrast, being younger than 25 years, being female, and living alone are significant predictors of an increased risk of unhealthy eating behaviours in the total number of students who participated in our survey. Again, the same regression models applied at T0 and T1 confirmed the sociodemographic factors are taken into account, except "living alone", which was not guaranteed to be a risk factor at T1, probably because the lockdown forced most of the students to return to their families. (Table 4).

At T1, we registered a high percentage of physical activities drop out and a change in the way of practising and the type of activity. Students declared to practise mainly those activities allowed by the COVID-19 restriction: outdoor and home fitness. On the other hand, there was a considerable change in the way they performed the activity for those who decided and were able to continue with their sport discipline. In the students analysed at T1, the increase in sedentary time was obviously due to the lockdown period that pushed them to spend more hours in front of the TV and the computer.

Table 4. Logistic regression models relating some sociodemographic variables and eating habits in the total sample and the two subsamples (T0 and T1).

		Eating Habits	
		OR	95% CI
TOTAL SAMPLE (n. 2001)			
Gender	female	2.7	2.21–4.90
	male	1	
Age	≤25	2.41	1.91–3.22
	≥26	1	
Relationship Status	live alone	1.45	1.06–2.91
	live with family	1	
T0 (n. 1025)			
Gender	female	2.85	1.77–4.25
	male	1	
Age	**≤25**	3.09	2.41–6.59
	≥26	1	
Relationship Status	live alone	1.29	1.01–2.21
	live with family	1	
T1 (n. 976)			
Gender	female	3.81	2.22–4.59
	male	1	
Age	≤25	3.57	2.55–5.00
	≥26	1	
Relationship Status	live alone		—
	live with family		—

Statistically significant differences $p < 0.001$.

4. Discussion

Our study aimed at investigating the eating and physical activity behaviours of university students in Italy before and during the COVID-19 pandemic trying to understand whether the extent of change, if any, may depend on specific individual and environmental factors.

The results of our study show changes in physical activity and eating behaviours before and after the pandemic.

Before the pandemic, about 40% of the students were physically active, especially male students and younger students. A decrease in the time spent in physical activities, a change in the type and level of PA, and an increase in sitting time and sedentary behaviours affected both men and women students, but men's PA behaviours seemed to be more affected by the isolation and quarantine. In our study, being male, older than 26 years old, and living in a household with parents with a low level of education were considered risk factors that led to being less active during the pandemic.

We also found differences in eating behaviours before and during the pandemic with an increase in the number of meals at T1.

Finally, we also found a significant increase in the percentage of overweight and obese students at T1.

The adoption of improper lifestyles in youth could be due to the fact that they tend to underestimate the probability of the negative consequences since they do not think that such events can happen to them [57–59]. A recent study found that university students were inclined to lead unhealthy lifestyles, and more specifically, their eating behaviours most of the time did not fulfil the recommendations [9].

According to previous studies, the main external barriers to PA practice in university students are the lack of time due to busy lesson schedules and parents' pressure on academic performance. Internal barriers such as lack of energy and motivation could also affect the low rates of PA at this age [60].

Concerning eating habits, we found that the majority of the student in the total sample ate three meals per day. The impact of meal frequency on overweight and obesity in

children and adults has been previously investigated, but the findings are far from being heterogeneous [61].

Previous studies on weight gain in university students showed that, compared to the same age individuals not attending colleges or universities, students have a higher probability of gaining weight and of being overweight, especially in the first year of university, primarily due to insufficient physical activity, poor diet, and stress that encourages bad habits such added snacks or skipping breakfast [62–64]. Although many university students know about balanced diets, increases in sugar, fat, and sodium intake and low consumption of fruits and vegetables appear to be common in this specific population, especially due to improper cooking and eating behaviours [65,66].

The BMI of our sample at T0 was very similar to the one described by Teleman et al. in 2015 for an example of Italian university students. The majority of students were of average weight, and male students were reported to be more overweight than females [21,22].

Both samples (at T0 and T1) mainly reported activities such as swimming, jogging, and fitness, and these findings are in line with the data related to the Italian adult population [67]. Motivations to practise sport and PA for our sample are mostly to be healthy, get rid of stress, and lose weight. Appearance, weight, and stress management are the motivations for exercise practice more reported by young adults and college students [68,69].

As per other recent studies on the impact of the COVID-19 pandemic on university students worldwide [70–75], our data showed changes related to PA, eating habits, BMI, and body image perception during the pandemic. More specifically, the descriptive analysis showed that the levels of PA decreased by 40% at T1.

These results confirm the findings of other studies on lifestyles of university students during the COVID-19 pandemic that recorded a decrease in the time spent in physical activities, a change in the type and level of PA, and an increase in sitting time and sedentary behaviours, with some differences depending on several sociodemographic and individual variables [38,44,70,76–80]. The changes in the way of practising physical activities, exercise, and sport during the pandemic were mostly due to the restrictive measure adopted by governments. Outdoor activities and home fitness have replaced many activities that were prohibited. On the other hand, there was a considerable change in the way they performed the activity for those who decided and were able to continue with their sporting discipline due to the unavailability of specific equipment and facilities [44]. However, some research highlighted that, despite the decreases in time spent in physical activity and the changes related to the type of activity, those who were achieving recommended levels of PA before the pandemic would appear to continue to reach them even during the lockdown, especially if younger than 22 years old, female, previously active, and with at least one graduate parent [78,79,81].

According to Brancaccio et al. (2021), the male population was more affected by isolation and quarantine, reporting more unfavourable behavioural changes during the COVID-19 pandemic [81].

We found that women were less active than men both before and during the pandemic, but men's PA behaviours seemed to be more affected by the isolation and quarantine. The difference in the adherence to PA between sexes confirms data from the Italian National Institute of Statistics [27] and data from other international studies [8]. We found that being male, older than 26 years old, and living in a household with parents with a low level of education were considered risk factors to be less active during the pandemic in our sample. Education was considered an indicator of socioeconomic position, and several studies before the pandemic showed evidence of a positive association with PA, especially during adolescence [82]. On the other hand, a longitudinal study analysing adults' PA before, during, and after COVID-19 restrictions did not find any significant association between socioeconomic status and changes in PA [83]. Moreover, women, as also demonstrated in another study on the Italian adult population, showed a lower tendency to reduce physical activity levels during the lockdown, revealing greater resilience than men [84].

In our study, eating behaviours also changed during the pandemic. More specifically, the students increased the number of meals at T1. The percentage of students eating five meals per day increased from 10.3% to 31.3%. These data align with the results of recent studies on the impact of the pandemic on dietary habits in various population groups that found that participants increased their meal number and frequency during quarantine [85].

A recent study about the effects of COVID-19 home confinement on eating behaviour, number of meals and snacks, food consumption, and type of food were recorded to have unhealthier patterns than before the pandemic in an international survey of adults [31].

We found that also BMI changed during the pandemic. According to the reported data on weight and height, the BMI calculated showed a significant increase in the percentage of overweight and obesity at T1. As discussed in other studies on the impact of COVID-19 on university students' BMI, it seemed that the changes in food consumption and physical activity negatively affected the students' BMI [86,87].

The regression analysis on eating habits for the total sample showed that female students younger than 25 years old and living alone have a higher risk of unhealthy eating behaviours. Our findings agree with the results of a study about dietary habits of university students in Italy that reported more difficulties in adopting a healthy diet in students living alone than the ones living with their families [88]. On the other hand, the interactions between sex and eating habits were not significant in a previous survey on eating habits and food-intake frequency in a sample of college students [89]. The regression analysis at T0 and T1 found the same risk factors as the total sample except for the variable named living alone, which does not appear to be a risk factor at T1. As expected, many students went back to live with their parents during the pandemic, which could explain the difference with T0.

Strengths and Limitations

University students are a fascinating group to study about lifestyle and health behaviours. Investigating university students' behaviours can be very useful in order to guide universities in setting up specific prevention strategies and awareness campaigns.

Our study was one of the first to investigate physical activity and eating behaviour in university students with data collection both before and during the COVID-19 pandemic.

However, the study has several limitations that should be addressed:

The sample lacks statistical representativeness due to the sampling procedure and the non-probabilistic strategies that could have led to a selection bias. However, using social media to promote the survey can be considered a low cost and fast way to collect data, especially in a pandemic situation [90].

A cross-sectional design could also be considered a limit since it measures the cause and the effect at the same point in time and cannot support findings on causal relationships. This design represents a clear and standardised method to determine the prevalence of health-related behaviour, such as wearing seat belts or participating in exercise [91,92].

Another limitation of the study is the validity of self-reported measures that could lead to overestimating or underestimating physical activity behaviours and being prone to inaccuracies when collecting data on eating behaviours [49,93–95]. Future studies should use more objective measures to perform a more precise assessment of these parameters [70].

Although the instrument used showed good statistical power, the questions concerning PA did not allow a very precise assessment of the energy expenditure. The use of a validated scale such as the International Physical Activity Questionnaire (IPAQ) [96], for example, would have allowed a better calculation of the MET expenditure and more accurate identification of PA levels. An assessment of the regulatory styles (intrinsic/extrinsic) in the students' intention to practise PA could also have helped provide further useful insights into the comparison between before and during the pandemic lockdown [97].

Moreover, when investigating eating habits, the specific dietary components intake and healthy dietary patterns were not assessed. Future research should try to use validated scales to build a composite diet quality index such as the Diet Quality Index -

International [98] and the Healthy Eating Index [99] to make the statistical analysis and the discussion of the results easier. However, previous studies already used meal frequency to assess the association with the prevalence of obesity and cardiovascular diseases [61].

The questions used to investigate physical activity and eating habits are adapted from the HBSC questionnaire. The items of the HBSC physical activity questionnaire have acceptable reliability and validity among international students [51].

When the first data collection was performed, our aim was to investigate several lifestyle habits at the same time in school-aged students and university students. Therefore, we decided to use questions from a validated international tool (translated into Italian) for its comparability value. When the second collection took place, even if the objective was to focus only on two habits, we decided to use the same questions to make the comparison more accessible and more statistically valid.

In addition, we acknowledge that the second version of the questionnaire lacks questions related to the exposure to COVID-19 infection (directly or indirectly). This variable could have influenced the behaviours associated with PA and a healthy diet.

Another possible limitation of the study could be the presence of selection biases and residual confounding bias. We tried to limit these biases with a sampling method (at T0 and T1) based on simple randomisation, a good size of the sample, and a regression analysis that could support us on the validity of the data that emerged.

Finally, one of the primary limits of the study was that participants did not coincide at T0 and T1 since when we collected the first data (T0), our aim was not to have a longitudinal investigation. This limit is common to other studies published during the unexpected event of the COVID-19 pandemic with different populations [37,49,100]. In order to reduce this limitation, using the same inclusion criteria is necessary to obtain two similar subsamples. In our case, we also attempted to collect data during the same time of year, which allowed a comparison in similar conditions of university commitment and general availability of leisure time (classes period instead of exams period).

5. Conclusions

Our findings suggested that during home isolation due to the COVID-19 pandemic, PA and eating behaviours were negatively affected in university students.

During the pandemic, the tendency of young people to gain weight, spend too many hours without moving, and adhere to healthy eating seems to have worsened, with differences between genders: male students seem to be more active than females but less careful about eating behaviours.

Adverse health behaviours tend to increase with age and become more pronounced when young people acquire autonomy and can therefore express their own preferences.

Nutrition and physical activity were central themes in health campaigns in the early nineties, but this centrality faded in the following years. Only recently, the topic has been taken up again, and a more significant information effort towards the whole population is needed since improving healthy eating behaviours and increasing PA levels are both social and individual responsibilities. Therefore, a multi-sector, multidisciplinary and culturally relevant population-based approach is required.

In an emergency situation such as the COVID-19 pandemic, it seems that the relationship among health behaviours is even more vital. Previous studies suggest that physical exercise leads to healthier nutritional choices, and psychological states, in turn, influence the decisions of university students [46]. Psychological pathways, especially motivation, behavioural intentions, and anxiety, could influence the adherence to healthy behaviour and should be further investigated in future studies in order to develop the best strategy to put in place, especially during emergency periods such as a pandemic [101].

Universities, not only the ones focussing on scientific and medical areas, should invest in the protection and promotion of health of their students with specific awareness programmes and include the protection and promotion of health in their core values (8).

Further research should repeat the survey in the post-lockdown period to investigate the long-term effects on physical activity, sedentary behaviour, and nutrition behaviours.

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Protocol

FOODLIT-Trial: Protocol of a Randomised Controlled Digital Intervention to Promote Food Literacy and Sustainability Behaviours in Adults Using the Health Action Process Approach and the Behaviour Change Techniques Taxonomy during the COVID-19 Pandemic

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Abstract: Dietary quality and sustainability are central matters to the international community, emphasised by the burden of the COVID-19 pandemic. To promote healthier and more sustainable food-related practices, the protocol of a web-based intervention to enhance adults' food literacy is presented. The FOODLIT-Trial is a two-arm, parallel, experimental, and single-blinded randomised controlled trial delivered over 11 weeks. Based on the Food Literacy Wheel framework and supported by the Health Action Process Approach (HAPA) and the Behaviour Change Techniques Taxonomy, weekly content with customised behaviour change techniques (experimental group) is hypothesised to be more effective to promote food behaviour change when compared to a single-time and non-customised delivery of food-related international guidelines, with no theoretically informed approaches (comparison group). Primary outcome is food literacy, including food-related knowledge, skills, and behaviours, assessed with the FOODLIT-Tool; a secondary outcome includes psychological mechanisms that efficaciously predict change in participants' food literacy, measured with HAPA-driven items. Enlisted through online sources, participants will be assessed across five time points (baseline, post-intervention, and 3-, 6-, and 9-month follow-ups, i.e., T0–T4). A randomisation check will be conducted, analyses will follow an intention-to-treat approach, and linear two-level models within- (T0–T4) and between-level (nested in participants) will be computed, together with a longitudinal mediation analysis. If effective, the FOODLIT-Trial will provide for a multidimensional and cost-effective intervention to enable healthier and more sustainable food practices over the long term.

Keywords: food literacy; behaviour change; Behaviour Change Techniques Taxonomy; Health Action Process Approach; randomised controlled trial; COVID-19

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1. Introduction

Both adequate nutrition and worldwide environmental sustainability are strongly sustained by global food systems. In the last decades, imposed by diverse anthropogenic sources, such as growing population and uncertainty of global economy, food systems have been facing major alterations that have deeply impacted food consumption behaviours [1–3]. Intricately linking human health and sustainability, food consumption patterns represent one of the greatest challenges of this century. Trending unhealthy meal patterns, often driven by needs of convenience and inadequate accessibility to nutritious foods, are characterised as high in caloric value, excessively processed, and rich in animal

source foods [3,4]. Leading to over 2 billion adults with overweight or obesity and a global prevalence of non-communicable diseases such as diabetes, unhealthy diets pose a greater risk to morbidity and mortality than those of unprotected sex, alcohol, tobacco, and drug use combined [3,5]. Moreover, with the global public health pandemic of COVID-19, food consumption behaviours are demonstrating an increased pattern of unhealthier diets during home confinements and other related restrictions across diverse countries [6].

Additional to increasing the burden of food-related diseases, these unhealthy dietary trends also play a crucial role in environmental degradation [7,8]. Food regimes identified as lose–lose diets—characterised by being both unhealthy and environmentally unsustainable—are not only described as high in saturated fats, added sugars, and red meats, but also represent a higher environmental burden, being associated with the transformation of natural ecosystems into croplands and threatening biodiversity with species' extinction [9]. With 40% of global land occupied by agriculture, and food production being accountable for up to 70% of freshwater use and 30% of worldwide greenhouse-gas emissions, a change in the global food system is needed to minimise its impact on both human health and environmental sustainability [3,10–12].

A shift towards improved nutrition and more sustainable food systems has been a concern to the international community, represented by global agendas such as the Sustainable Development Goals integrated within the 2030 Agenda [13], its Food Systems Summit [14], and the Decade of Action on Nutrition [15]. However, this shift will not thrive without a simultaneous bottom-up transformation; it is crucial that people change how they view, understand, and engage with food systems, ultimately changing their food-related knowledge, competencies, and behaviours—that is, their food literacy [3,4,16,17].

1.1. Food Literacy

Designated as crucial to protect the quality of diets across the lifespan, food literacy has been gaining prominence across research, practice, and policy during the last decade [18–23]. Generally seeking to improve nutrition knowledge and food-related skills, most programmes and interventions developed within the scope of food literacy either (i) exclusively feature nutrition information [24–26], (ii) are targeted towards younger populations and often developed in an educational context [27–31], and/or (iii) narrowly focus on preparation or cooking skills, not emphasising other food-related competencies (e.g., planning, acquisition) [21,25,28,32]. More importantly, current interventions do not provide for knowledge to face the complexity of today's food environment, nor the competencies to deal with it and navigate within aiming for healthier food patterns; consequently, food-related behaviour change is limited [32].

Acknowledging the intertwined relation among food system stakeholders and individuals' food literacy, and its relevance in order to tackle major challenges concerning global sustainability, this team developed the Food Literacy Wheel (FLW) [16] and the FOODLIT-Tool [17]. The first is a conceptual and empirical framework of food literacy, comprehending not only the set of food-related knowledge, competencies, and behaviours but also its determinants (such as convenience and practicality, time and financial management, access to food information, and professionals' unpreparedness on food-related expertise) and influential factors (psychological and learning surroundings, policy and industry settings, sustainability and social contexts, among others). The second concerns a validated and reliable instrument to assess the food literacy of adults based on the FLW; this quantitative measure allows for its own tailoring to diverse contexts and intends to evaluate one's food literacy, its determinants, and influential factors, as a resource to promote behaviour change towards more healthier and sustainable food habits.

Aiming to make a contribution for the development of food-related competencies, attainment of healthier eating habits and achievement of more sustainable practices within one's diet, the FOODLIT-Trial will integrate both the FLW and the FOODLIT-Tool on a digital intervention to promote food literacy and sustainability behaviours in adults.

1.2. Digital Interventions to Promote Behaviour Change

The use of technology within the daily life of developed countries' population has gained particular relevance in recent years, being even more emphasised by the current COVID-19 global pandemic. With almost 90% of European households having online access and more than 70% adults affirming the use of online resources on an everyday basis, studies conducting digital interventions aiming for behaviour change have become widespread [33–35]. Particularly in the scope of health promotion, food consumption has been one of the most mainstream topics for the use of digital technologies; accounting for daily activities, the potential for food-related behaviours (such as purchasing, cooking, or eating) to be changed through digital solutions, such as web-based self-guided programmes and smartphone applications, is significantly appealing [35,36]. However, with the increase in digital interventions for the promotion of food-related healthier and sustainable behaviours, various trends have emerged. Within the theme of food sustainability, targeted behaviours have mainly focused on the reduction of food waste [37–40]; food-related competencies, purchasing, and cooking have been the most recurrent aimed behaviours [41–43]. The predominance of programmes targeted at younger populations [44,45] or specific to clinical conditions [46,47] is also notorious. Particularly concerning food literacy, the use of digital tools to promote food-related knowledge, competencies, and behaviours is still taking its first steps; either featuring technology or not, the prevalence of a younger target across food literacy interventions and programmes is evident [22,31,32,48]. More recently, however, the adult population has been targeted in research-based interventions [49–52], and digital resources remain scarce in the field.

Another noticeable characteristic of digital interventions to promote for healthy, sustainable, and knowledgeable food-related behaviours is the lack of clear theoretical backdrop to sustain behavioural change. The majority of these studies are scarcely grounded on a behavioural change theory [37,38]; most report an increase in participants' awareness but do not explore longitudinal and evidence-based behaviour change [35]. Limitations of previous studies include lack of baseline data, lack of control or comparisons group, and lack of longitudinal follow-up data [35,43,49].

Addressing the promotion of healthier and more sustainable food-related knowledge, competencies, and behaviours through a digital and online intervention, the FOODLIT-Trial is grounded in the Health Action Process Approach (HAPA) [53,54] and applies behaviour change techniques from a consensual taxonomy (Behaviour Change Techniques Taxonomy (BCTT)) [55], aiming to lead to effective and sustained food behaviour change.

1.3. Study Objectives and Hypothesis

This study presents the detailed research protocol of a randomised controlled trial (RCT) to assess the efficacy of a web-based intervention in enhancing adults' food literacy, using (i) digital evidence-based resources, (ii) behavioural change techniques from the BCTT [55], and (iii) the HAPA framework [53,54] as a theoretical backdrop.

The study's primary objective is to evaluate whether the developed digital intervention is effective in improving food-related knowledge, competencies, and behaviours, based on the FLW [16] and evaluated with the FOODLIT-Tool [17]. Potential differences in participant's food literacy over time will also be assessed with a longitudinal design. We hypothesise that the use of a web-based intervention combined with behavioural change strategies (customised to each food-related skill) will be more effective to enhance food literacy than the approach used with the comparison group (single-time delivery of non-customised food-related national and international guidelines, without any additional theoretically informed, evidence-based behaviour change approaches). The second objective is to understand the intervention performance, by evaluating which psychological mechanisms, such as self-efficacy, planning, and action control [53,54], efficaciously determine change in participants' food literacy. It is hypothesised that HAPA-derived mechanisms will significantly mediate the participants' outcomes concerning food literacy.

2. Methods and Analysis

2.1. Trial Design

The FOODLIT-Trial is a two-arm (allocation ratio 1:1), parallel, experimental, and single-blinded randomised controlled trial for Portuguese adults (Figure 1). The web-based intervention is delivered over 11 weeks, where each week is themed with content either according to the FLW framework or to the HAPA model.

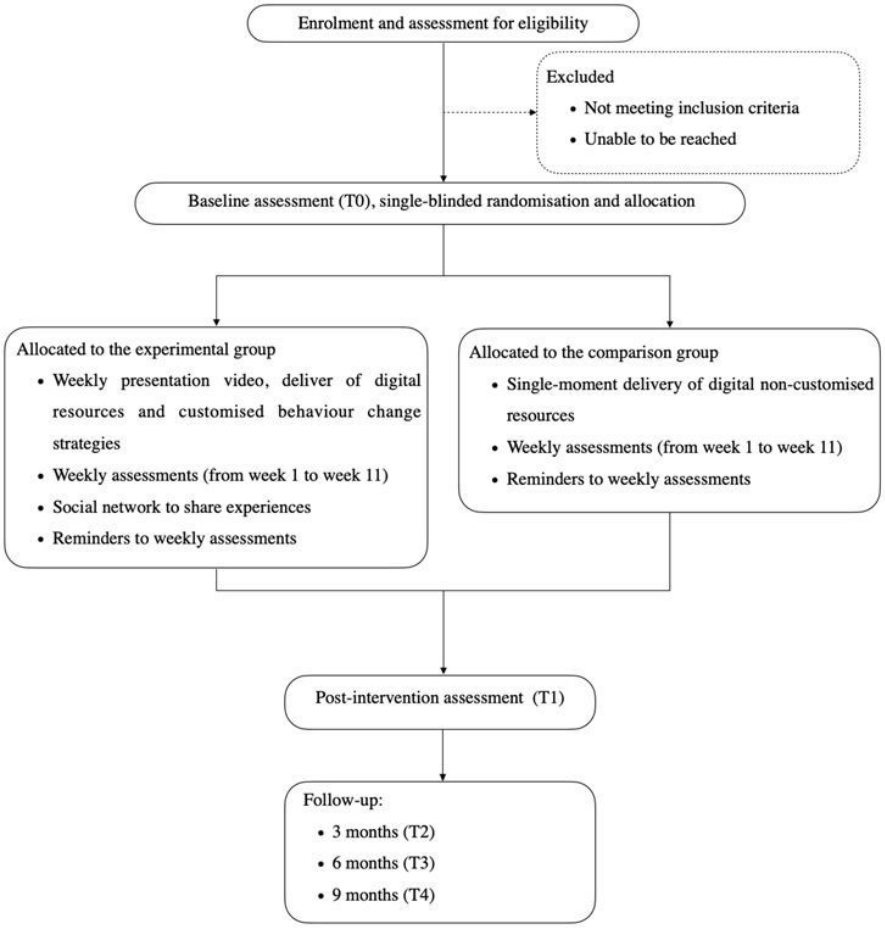


Figure 1. Flowchart of the FOODLIT-Trial intervention, including both experimental and comparison groups.

In conformity to the week's thematic, each ability, skill, and behaviour is matched with a behavioural change strategy to facilitate its implementation [55]. All measures will be assessed at five time points: baseline (T0), to measure baseline characteristics, pre-intervention, before randomised allocation, and prior to the trial's first week; post-intervention (T1); one week after the 11-week intervention delivery; and at follow-up times 3, 6, and 9 months after the intervention (T2, T3, and T4, respectively).

This protocol adheres to the Consolidated Standards of Reporting Trials [56] guidelines for randomised controlled trials.

2.2. Ethical Approval

As part of a major project titled FOODLIT-PRO: Food Literacy Project, this study was approved by the Ethics Committee of Ispa—Instituto Universitário (ref. D/002/03/2018). The FOODLIT-Trial was developed according to the Declaration of Helsinki, followed the deontological norms and ethical principles of the Order of Portuguese Psychologists [57], and adhered to General Data Protection Regulation [58]. This protocol was approved and registered by ClinicalTrials.gov (NCT04806074).

2.3. Participants and Recruitment

Considering its web-based format, FOODLIT-Trial's potential participants will represent a sample of convenience and snowballing, and will be reached and enlisted through online sources. Online reach out will be made by using both advertisements in social media websites according to the researcher's network (Instagram and Facebook, Meta Platforms: Cambridge, MA, USA) and a developed website for participants' enrolment. During the recruitment stage, potential participants will be informed that trial participation will entail compensation in order to acknowledge their time and effort dedicated to the study.

An a priori power analysis was conducted with G*Power (v. 3.1), and a minimum sample size of 28 was necessary in order to detect a medium effect size (Cohen's d = 0.50) at the 5% level of significance with 95% power, with the assumption of the non-violation of sphericity (non-sphericity correction $\varepsilon = 1$) considering the trial's repeated-measures design. Given a potential attrition rate of 50% due to the digital nature of the trial, its duration, and required weekly assessments, a minimum of 56 participants will be recruited.

Participants for the FOODLIT-Trial must (i) be adults aged 18 years or older, (ii) be able to understand and read Portuguese, (iii) have availability to engage in the 11-week trial, and have internet access that allows for their engagement, (iv) be responsible for, at least, one out of four tasks in their food routine (encompassing choice and decision, selection and acquisition, preparation, and cooking, according to [18]). Potentially eligible participants will be invited to the trial through an online information sheet, and will be provided with the consent form; if eligible, the baseline questionnaire (T0) will be made available and delivered online. Additionally, all participants will be asked to complete a sociodemographic questionnaire aiming to collect self-reported data concerning sociodemographic and health-related characteristics (e.g., sex, age, educational level, diagnosed diseases, height, weight).

2.4. Randomisation and Blinding

Consenting participants meeting inclusion criteria will be randomised and allocated to either the experimental group (EG) or the comparison group (CG), following the baseline period. At baseline, each participant will create a unique code (based on the name's initials and year of birth) to allow for longitudinal correspondence along the different time points. Randomisation will then be performed using a computer-generated random 1:1 allocation list. Knowledgeable concerning the specifications of the trial arms in the consent form, all participants will also be informed that both groups will (i) be contacted weekly to take part in every assessment, (ii) receive the same online reminders through digital sources (email and WhatsApp, Meta Platforms: Mountain View, California), and (iii) be featured in the compensation mechanism. As such, randomisation results will be concealed from participants at all moments. It will not be possible to apply this to the research coordinator (RR), given her responsibility to create and deliver the weekly customised resources to the EG. Thus, the FOODLIT-Trial's allocation will be single-blinded for its participants.

2.5. Intervention

The FOODLIT-Trial is an online-enabled intervention to promote food literacy and food sustainability practices delivered with digital evidence-based resources in multiple formats, based on theoretically informed behaviour change approaches, and made available through mobile phone, tablet, and computer. The intervention will include weekly reminders for participants to evaluate their food-related knowledge, competencies, and behaviours, and assess related psychological mechanisms associated with behaviour change. Experimental and comparison group specifications are described below.

2.5.1. Experimental Group

Participants allocated to the EG will receive weekly information concerning a specific theme through digital sources such as videos, infographics, and web-directed links. The 11-week intervention is designed according to (a) the food-related knowledge, competencies,

and behaviours belonging to the core of the FLW conceptual and empirical model, and (b) the psychological mechanisms within the HAPA framework. As shown in Table 1, each week entails not only a set of skills, behaviours, and/or mechanisms that feature the above mentioned theoretical and empirical frames, but also a customised, well-defined, and identifiable technique from BCCT to prompt participants' food-related behaviour change.

Table 1. Description of the experimental group intervention, including (i) the weekly thematic; (ii) its correspondent frameworks, including the Food Literacy Wheel (FLW) and the Health Action Process Approach (HAPA); (iii) the instruments used for weekly assessment, entailing either items from the FOODLIT-Tool or the HAPA; and (iv) the identification of the each behaviour change technique (BCT) used across all weeks, customised to the thematic's content.

Week	Framework	Instruments	Behaviour Change Techniques
Thematic	Variables or dimensions	Dimensions and/or items	BCTs title
Week 1	**HAPA**	**HAPA**	**Total: 3 BCTs**
Pre-intenders	Action self-efficacy	Five items	(15.1) Verbal persuasion about capability
	Risk perception	Three items	(5.1) Information about health consequences
	Outcome expectancies	Nine items	(9.3) Comparative imagining of future outcomes
Week 2	**FLW**	**FOODLIT-Tool**	**Total: 2 BCTs**
Origin and conservation	Choice and acquisition	*Origin* Items 17 and 18	(4.1) Instruction on how to perform the behaviour
	Preserve and analyse	*Culinary competencies* Item 10	(4.1) Instruction on how to perform the behaviour (6.1) Demonstration of the behaviour
Week 3	**FLW**	**FOODLIT-Tool**	**Total: 4 BCTs**
Prepare and adapt	Cooking Skills	*Culinary competencies* Item 1	(1.4) Action planning (4.1) Instruction on how to perform the behaviour (6.1) Demonstration of the behaviour
		Item 2	(4.1) Instruction on how to perform the behaviour
		Item 3	(15.1) Verbal persuasion about capability
Week 4	**FLW**	**FOODLIT-Tool**	**Total: 3 BCTs**
Cooking	Cooking Skills	*Culinary competencies* Item 4	(6.1) Demonstration of the behaviour
		Item 8	(1.1) Goal setting (behaviour) (4.1) Instruction on how to perform the behaviour (6.1) Demonstration of the behaviour
Week 5	**FLW**	**FOODLIT-Tool**	**Total: 1 BCT**
Choice and selection	Choice and acquisition	*Selection and planning* Item 20 Item 21	(4.1) Instruction on how to perform the behaviour *(in both items)*
Week 6	**HAPA**	**HAPA**	**Total: 3 BCTs**
Intenders	Maintenance self-efficacy	Six items	(15.3) Focus on past success
	Action planning	Five items	(1.4) Action planning
	Coping planning	Six items	(1.2) Problem solving

Table 1. *Cont.*

Week	Framework	Instruments	Behaviour Change Techniques
Week 7	**FLW**	**FOODLIT-Tool**	**Total: 3 BCTs**
Nutrition and intake	Cooking Skills	*Culinary competencies* Item 5	(6.1) Demonstration of the behaviour
	Preserve and analyse	*Selection and planning* Item 16	(2.4) Self-monitoring of outcome(s) of behaviour
	Choice and acquisition	Item 19	(6.1) Demonstration of the behaviour
	Search and plan	Item 24	(4.1) Instruction on how to perform the behaviour
Week 8	**FLW**	**FOODLIT-Tool**	**Total: 4 BCTs**
Planning and cooking pleasure	Cooking skills	*Culinary competencies* Item 9	(5.6) Information about emotional consequences (10.4) Social reward
		Selection and planning Item 25	(4.1) Instruction on how to perform the behaviour *(in both items)*
	Search and plan	Item 26	(6.1) Demonstration of the behaviour *(in both items)*
Week 9	**FLW**	**FOODLIT-Tool**	**Total: 2 BCTs**
Hygiene and safety (within production and kitchen)	Preserve and analyse	*Environmentally safe* Item 11	(4.1) Instruction on how to perform the behaviour (6.1) Demonstration of the behaviour
		Production and quality Item 12 Item 13 Item 14	(4.1) Instruction on how to perform the behaviour *(in all items)* (6.1) Demonstration of the behaviour *(in all items)*
Week 10	**FLW**	**FOODLIT-Tool**	**Total: 2 BCTs**
Local and seasonal	Preserve and analyse	*Environmentally safe* Item 15	(5.3) Information about social and environmental consequences
	Search and plan	Item 22 Item 23	(4.1) Instruction on how to perform the behaviour *(in both items)*
Week 11	**HAPA**	**HAPA**	**Total: 3 BCTs**
Actors	Recovery self-efficacy	Three items	(8.7) Graded tasks
	Action control	Six items	(1.6) Discrepancy between current behaviour and goal (2.3) Self-monitoring of behaviour

Participants in the EG will receive weekly (A) evidence-based and customised information related to a specific skill, behaviour, and/or mechanism, from sources such as national and international guidelines—namely, the Portuguese Directorate-General for Health and the EAT-Lancet Commission on Food, Planet, Health; (B) designated tasks based on each behaviour change technique and related to the week's thematic; (C) a short introductory video, featuring the research coordinator, briefly mentioning the week's thematic and alerting to the week's assessment; (D) notifications reminding the need to respond to the week's questionnaire (two days before the end of the week and the day of the due date for questionnaire response) and the corresponding link leading to the week's questionnaire. All materials, except for the weekly questionnaires, will be stored in a purposely created website, allowing for participants to revisit previous weeks' resources (if desired).

Shown in Table 2A is two-week example of (A) a customised infographic, (B) its associated task based on a behaviour change strategy, and (C) its corresponding items.

Table 2. Example of the FOODLIT-Trial's experimental group Week 4 (themed Cooking) and Week 11 (themed Actors), entailing (A) customised infographics; (B) its associated tasks, presented within the infographics and reflecting the behaviour change strategies applied; and (C) corresponding items, to be responded to before the end of the week.

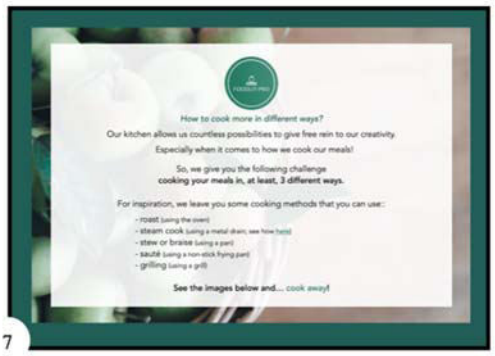
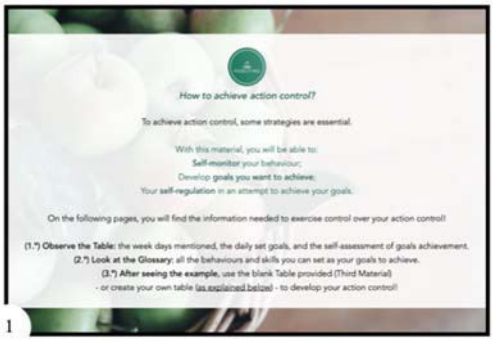
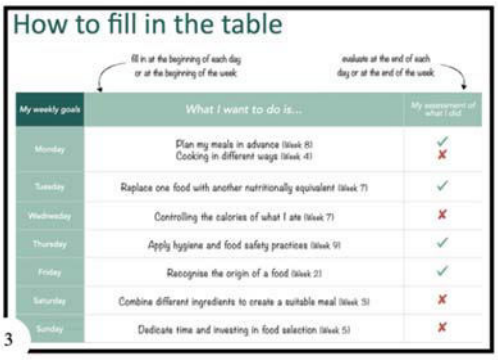
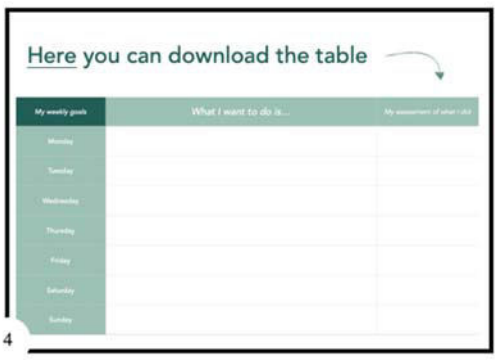
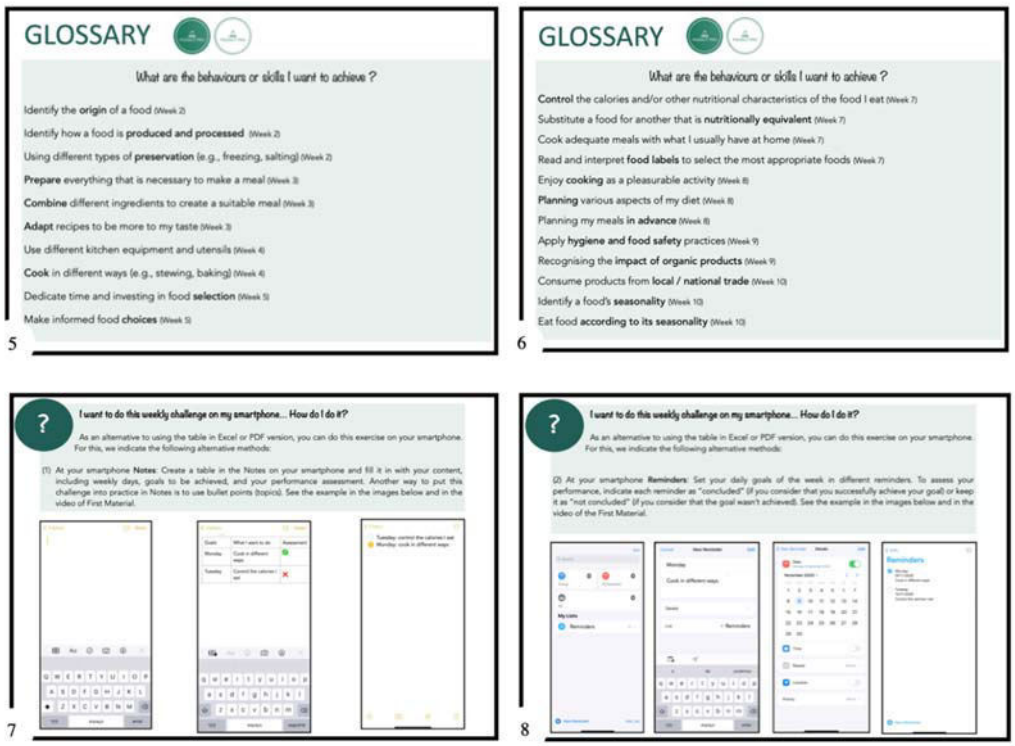
Week 4—Cooking
Customised infographics (A) and its associated tasks (B), reflecting the behaviour change and strategies applied.
 
Corresponding items (C), to be responded to before the end of the week. Item 4 *I use kitchen equipment and utensils (e.g., oven, blender) efficiently.* Four-point Likert-type response scale (0—*never;* 1—*sometimes;* 2—*frequently;* 3—*always*). Item 8 *I cook in different ways (e.g., stewing, baking).* Four-point Likert-type response scale (0—*never*; 1—*sometimes*; 2—*frequently*; 3—*always*).
Week 11—Actors
Customised infographics (A) and its associated tasks (B), reflecting the behaviour change strategies applied.
   

Table 2. *Cont.*

Week 11—Actors

Corresponding items (D), to be responded to before the end of the week. **Recovery self-efficacy** (three items) *I believe that I could return to having a diet adequate to my needs, even if:* (1) *I had spent a few days without doing so.* (2) *I had spent many days without doing so.* (3) *I had spent a few weeks without doing it.* **Action control** (six items) (1) *I have evaluated regularly when, where and how I am making an adequate diet suited to my needs.* (2) *I have assessed my behaviour daily to check if I am having an adequate diet.* (3) *I am always aware of the diet that is adequate to my needs.* (4) *I have always in mind the intention to make a diet adequate to my needs.* (5) *I have worked hard to have a diet that meets my needs on a regular basis.* (6) *I have been making the effort to have an adequate diet as much as I intend to.*

2.5.2. Comparison Group

Participants allocated to the active CG will receive a single-time and non-customised delivery of the same food-related national and international guidelines. There will be no theoretically informed approach and no behaviour change techniques, and the delivered content will generically regard nutritious eating and food-related habits. No digital presence of the research coordinator will be featured to the CG (that is, no weekly introductory videos will be sent to this cohort). Additionally, to the (A) single-time (but non-customised) delivery of informative guidelines from the same entities, the CG will receive (D) the identical notifications serving as reminders for the weekly questionnaires (identical to the questionnaires delivered to the EG). Similarly to the EG, the guidelines will be stored in a specifically designed website, providing for uninterrupted access.

2.6. Adherence and Strategies to Minimise Drop-Out

To encourage intervention adherence and engagement, weekly reminders will be sent to participants of both EG and CG via email and/or WhatsApp. At the beginning of each

week, the reminder will be sent via WhatsApp, notifying participants that a new week of FOOLIT-Trial is starting and that the weekly welcoming email was sent; for the EG, a link enabling the access to the week's resources (A, B, and C) will be featured, while CG participants will be reminded of the access to where guidelines are stored (non-customised A). Two days before the end of each week, an email will be sent in the morning with the link leading to the week's questionnaire; a notification through WhatsApp will be delivered later that day reminding that the link for questionnaire response is already available. At the due date for the weekly response, a final reminder will be sent through WhatsApp, indicating that the questionnaire will be available until the end of that day.

Additionally, as a strategy to minimise drop-out and to prompt continuous engagement, compensation will be featured within the FOODLIT-Trial. Compensation will entail the following randomised allocations of gift cards to participants for grocery shopping: (i) one gift card at the end of the 11-week intervention (with a credit of 50 EUR), (ii) a gift card at the end of the first and second follow-up (T2 and T3; a total of two gift cards with a credit of 25 EUR each), and (iii) two gift cards at the end of the last follow-up (T4; each gift card with a credit of 50 EUR).

2.7. Outcomes

2.7.1. Primary Outcome Measure

Considering FOODLIT-Trial's first aim, the primary outcome to be assessed is food literacy. Food-related knowledge, competencies, and behaviours will be assessed with the FOODLIT-Tool [17] at baseline (T0), during the 11-week intervention (with the items distributed across the theme for the week; Table 1), post-intervention (T1), and at all follow-ups (T2, T3, and T4). These longitudinal assessments will evaluate participants' food literacy according to the five dimensions portrayed in the instrument (Culinary Competencies, Production and Quality, Selection and Planning, Environmentally Safe, and Origin) and based on the FLW [16]. These include (i) theoretical knowledge, such as knowing various types of food preservation suitable to different foods (item 10); (ii) practical competencies, as interpreting food labels to select adequate foods (item 19); and (iii) food habits and behaviours, such as eating foods according to their seasonality (item 22). All items are assessed with a four-point Likert-type response scale, concerning either frequency (0—*never*; 1—*sometimes*; 2—*frequently*; 3—*always*) or agreement (0—*completely disagree*; 1—*disagree*; 2—*agree*; 3—*completely agree*).

2.7.2. Secondary Outcome Measure

Aiming to explore intervention performance, FOODLIT-Trial's second aim is to evaluate which psychological mechanisms efficaciously predict change in participants' food literacy. To achieve this objective, psychological mechanisms derived from the HAPA—including risk perception, outcome expectancies, self-efficacy, planning, and action control—will also be assessed at similar time points (from T0 to T4). All measures to evaluate HAPA constructs are adapted from Sniehotta, Scholz, and Schwarzer [59] and are specific to food literacy, depicting eating according to one's needs as the intended behaviour. All items are also assessed with four-point Likert-type response scales, regarding agreement (0—*totally disagree*; 1—*disagree*; 2—*agree*; 3—*totally agree*) and possibility (0—*very unlikely*; 1—*unlikely*; 2—*likely*; 3—*very likely*).

3. Statistical Analyses

3.1. Randomisation Check, Drop-Out Analyses, and Intention to Treat

A randomisation check will address equal distributions of all baseline measures of all primary and secondary outcomes and covariates across conditions using multivariate analyses of variance interval–scale data, and chi-square tests for nominal and ordinal-scale data. Analyses will be carried out in an intention-to-treat manner, accounting for missing values using the full information maximum likelihood approach [60]. Drop-out analyses

will test baseline differences between continuers and non-continuers in all variables using t-tests, chi-square tests, or logistic regression.

3.2. Hypotheses Tests for Intervention Effects

Linear two-level models with five time points (T0, T1, T2, T3, T4; within-level) nested in participants (between-level) will be computed. For each outcome measure, time (linear day trend, centred at 0) x experimental condition (0 = comparison condition; 1 = intervention condition) interactions will be estimated. Moreover, grand-mean centred covariates (e.g., sex, age) will be added as between-level predictors. The linear time trend and the linear time trend x experimental condition interaction will be modelled as fixed effects.

3.3. Examining Intervention Mechanisms

To explore the assumptions of the HAPA, a series of longitudinal mediation analyses will be conducted using manifest or latent path analyses. Experimental condition will be specified as a dummy-coded independent variable, proposed cognitive mechanisms as mediators, and food literacy factors as the outcomes (with or without control for respective baseline assessments). Because of the flexible conceptual framework of HAPA, reasonable time points (T1–T4) will be explored to identify the most useful mediators (e.g., self-efficacy, outcome expectancies, behavioural intention, planning) within the entire time span of the study. Bias-corrected bootstrap confidence intervals (95%) of direct and indirect effects will be generated by bootstrapping with 5000 re-samples.

4. Dissemination Plan

The study protocol is the first publication of this RCT. Findings of this RCT will be published in peer-reviewed international journals and at national and international conferences. Dissemination of results in journals will comply with CONSORT guidelines. Important protocol modifications will be reported.

5. Conclusions

By introducing the research protocol of a RCT that aims to evaluate the efficacy of a digital intervention to promote adults' food literacy, this study highlights not only the use of web-based resources to tackle food-related competencies and behaviours, but also addresses the need to design and apply a trial based on strong theoretical foundations linked to health behaviour change. We hypothesise that the support allowed by the delivery of digital materials entailing behavioural change strategies customised to food literacy-related information will improve food knowledge, competencies, and behaviours. A secondary hypothesis is that mechanisms acknowledged as part of a theoretical background to promote behaviour change will mediate these food literacy outcomes. To achieve the hypothesised outcomes, this team developed an 11-week plan that (A) gathers evidence-based resources based on national and international guidelines, (B) designates specific and diversified tasks based on behaviour change techniques, (C) provides for a multiple thematics, and (D) shares online notifications.

Presenting the first known randomised digital intervention to integrate behavioural strategies, based on a validated taxonomy and a theoretical framework of behaviour change in the field of food literacy, the FOODLIT-Trial intends to contribute to the promotion of healthier and more sustainable food habits during a global public health pandemic. With growing evidence on the impact of the COVID-19 pandemic on consumers' food patterns and worldwide food security [2,61,62], it is urgent to provide for mechanisms that promote positive change on food-related competencies and behaviours, while providing for strategies that guide one's navigation within this transformative food system. Accounting for a specific web-based platform for the delivery of digital resources and integrating online communication throughout the intervention, the FOODLIT-Trial transforms extensive international recommendations into thematic weekly challenges with the expectation to advocate for more informed food knowledge and more adequate and sustainable eating

habits in adult population. If effective, this intervention—along with its assessments of the FOODLIT-Tool and its conceptual basis from the FLW—has the potential to be adapted and applied across multiple professional contexts, allowing for a digital cost-effective resource that promotes healthier and more sustainable food habits according to international guidelines.

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Review

Micronutrient Deficiency as a Confounder in Ascertaining the Role of Obesity in Severe COVID-19 Infection

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Abstract: Food insecurity in the United States has been exacerbated due to the socioeconomic strain of the coronavirus disease 2019 (COVID-19) pandemic. Populations experiencing poverty and, as a consequence, food insecurity in the United States are disproportionately affected by obesity, which was identified early in the pandemic as a major risk factor for increased susceptibility to COVID-19 infection and mortality. Given the focus on obesity and its role in immune dysregulation, it is also important to note the role of micronutrient deficiency, another sequalae of food insecurity. Micronutrients play an important role in the ability of the immune system to mount an appropriate response. Moreover, OBESE individuals are more likely to be micronutrient deficient. This review will explore the role of micronutrients, vitamin A, vitamin D, vitamin C, and zinc in respiratory immunity and COVID-19 and how micronutrient deficiency may be a possible confounder in obesity's association with severe outcomes. By illuminating the role of micronutrients in COVID-19, this paper expands the discussion from food insecurity and obesity to include micronutrient deficiency and how all of these interact in respiratory illnesses such as COVID-19.

Keywords: micronutrients; vitamin D; vitamin A; coronavirus; SARS-CoV-2; COVID-19; respiratory infection; obesity; food insecurity

1. Introduction

Obesity was highlighted early in the coronavirus disease 2019 (COVID-19) pandemic as a major risk factor that predisposes patients to worse outcomes, with morbidly obese persons facing a 26% higher risk of death [1]. As a chronic inflammatory state, obesity disrupts the immune system and mechanically strains the respiratory system [2]. Populations that experience food insecurity, defined as having limited access to high-quality foods that may affect eating patterns and reduce food intake, have high rates of obesity in the United States (US) [3]. From 1999 to 2016, this population has doubled and the association between adiposity and food insecurity has increased [4]. People who are classified as being overweight

or obese, defined as an increased body mass index (BMI $\geq$ 25 kg/m^2 or $\geq$30 kg/m^2), have a nearly two-fold increased likelihood of having COVID-19 infection or complications [5–7]. Richardson and colleagues reported that over 40% of patients hospitalized with COVID-19 in the New York area in March and April of 2020 were overweight (BMI $\geq$ 25 kg/m^2) or obese (BMI $\geq$ 30 kg/m^2) [8]. These studies and others reinforce that not only are overweight patients at a greater increased risk for COVID-19 than patients who are not overweight, but those who are obese also have a greater risk than overweight patients [9–12]. Such findings are critical for public health messaging, clinical care, and lifestyle recommendations since obesity is present in nearly half of the adult citizens in America.

Obesity is directly linked to the maldistribution of the many social determinants of health (SDoH), including but not limited to food supply, housing, economic and social relationships, transportation, employment, criminal justice, education, and health care and the programs and policies that direct them. The maldistribution of SDoH effectively determines the length and quality of life across populations [13] by having a major influence on both nutrition and SARS-CoV-2 infections [14]. Poverty is one of the most significant, yet understudied, SDoH [15]. Poverty has been defined in several ways but may be summarized as the paucity of resources required to meet basic human needs. The setting of poverty exacerbates a downstream cascade of poor health including poor nutrition, micronutrients deficiency, and obesity. The impact of poverty and malnutrition have become magnified during the COVID-19 pandemic, especially as it has become clear the economically disadvantaged are beset with greater rates of infection by SARS-CoV-2 [16]. Poverty has been overlooked recently with a large focus on prosperity associated with the rise in global wealth [17]. The inequitable distribution of economic and financial resources has conspired to widen the gap between the affluent and poor, with global extreme poverty (individual income < USD1.90/day) having increased in 2020 during the first year of the pandemic, resulting in the first increase in over 20 years reaching 9.2%, from a low of 8% in 2019 [18].

By global standards, the prevalence of extreme poverty in the US is very low [18]. However, among the developed nations, the US not only has one of the highest rates of poverty, it also has the worst index of social and health problems when assessed as a function of income inequality [19]. Both inequities in wealth and rates of poverty in the US vary by race and ethnicity, with most racial and ethnic minority groups having twice the prevalence of poverty, as well as obesity and COVID-19 infections and complications [20].

Income inequality in Los Angeles County (LAC) exceeds that of the United States as a whole, with 17% of the population living below the federal poverty level in 2017 [21]. It is no surprise that LAC has been one of the hardest hit regions by the COVID-19 pandemic in the US, with mortality rates in Black and Latino/a Americans nearly two and three times that of White Americans and the largest food-insecure population in the US. In LAC, as with the rest of the county, public panic resulted in consumers rushing to stockpile groceries and necessities, and many households were left without basic food and supplies [22]. In April 2020, the number of food-insecure individuals increased from one out of five to one out of every three adults in LAC [23]. COVID-19 exacerbated the conditions leading to food insecurity by interfering with access to employment, income, and education. School closures led to 600,000 students in LAC and 55 million students across the US, unable to attend school in person, [24–26] resulting in the 85% of children, who otherwise qualify, unable to access free school meals [27]. With limited access to free meals as well as outside activities, the pandemic further exacerbated disordered eating and obesity among youth [28,29]. Given this, much focus has shifted to understanding the role of food insecurity and obesity in COVID-19 infections and outcomes.

However, in addition to increased adiposity, food insecurity can also lead to micronutrient deficiency [30–33]. Micronutrients are integral to the immune system's ability to mount an appropriate response, vital to the development and expression of the body's biological structures and processes. While micronutrient deficiency can result from food insecurity itself, it is potentiated by obesity which can lead to undernutrition in vitamins

and minerals [34]. We conducted a search in Medline (via PubMed) using the keywords "COVID-19" AND "Obesity" AND "Vitamin D" OR "Vitamin A" OR "Vitamin C" OR "Zinc" OR "Micronutrients", including underlying index terms and alternative variations of terms, to ascertain the relevant articles. The relevant studies published between 2019 and 2021 and select references citied in these articles were included. We performed a similar search in clinicaltrials.gov to gain an understanding of the number and types of registered ongoing trials in this area. We describe below the potential associations between commonly cited micronutrient deficiencies, vitamin A, vitamin D, vitamin C, and zinc and their relationship with obesity in patients with COVID-19.

2. Micronutrients and Severity of Respiratory Infections

2.1. Vitamin D

Of all the micronutrients studied, the impact of vitamin D deficiency has been evaluated by at least 92 clinical trials examining the association of vitamin D and COVID-19. Vitamin D is a fat-soluble micronutrient that comes from exposure to sunlight and diet. It undergoes metabolism in the liver to 25-OH vitamin D, the storage form of vitamin D, which is converted to calcitriol, the active form of vitamin D [35]. The ideal serum level of 25-OH D and the level at which patients are considered deficient/insufficient are controversial [36]. The Institute of Medicine (IOM) has recommended serum vitamin D concentrations should be maintained at 20–50 ng/mL, while serum 25-OH D concentrations less than 12 ng/mL are generally acknowledged as deficient as they are associated with an increased risk for bone and mineral disorders and cardiovascular and other diseases [36]. Unfortunately, the effects of vitamin D repletion on clinical outcomes such as cardiovascular disease, fractures, kidney disease progression, and mortality are not well established, but may be related in part to patient heterogeneity and study design. Recent systematic reviews suggest that vitamin D repletion is unlikely to have substantial positive impacts on mortality, cardiovascular disease, and other clinical outcomes in the general population [37], but its role in specific disease states is yet to be determined. The Endocrine Society recommends 25-OH D levels below 20 ng/mL be termed vitamin D deficiency, concentrations of 21–29 ng/mL to be termed insufficient, and normal levels should be reserved for serum 25-OH D values above 30 ng/mL [38]. Importantly, the terms 25-OH D deficiency and insufficiency are not necessarily representative of explicit disease states but a spectrum of risk for adverse outcomes related to low vitamin D levels [39]. Moreover, for a given population defined by age, race/ethnicity, and other characteristics such as co-morbidities, the prevalence and implications of vitamin D deficiency/insufficiency may vary [36]. This is highly relevant when considering the role of 25-OH D levels below 20 or ng/mL in COVID-19 positive patients who may present with other micronutrient deficiencies, oxidative stresses, and other relevant factors.

While it is best known for its role in bone metabolism, vitamin D has also been shown to be an active part of respiratory immunity. The respiratory epithelium has been found to generate a microenvironment with high levels of calcitriol due to its ability to constitutively activate vitamin D [40]. Calcitriol binding to Toll-like receptors on macrophages induces the activation of more vitamin D, the expression of more vitamin D receptors, and synthesis of downstream products [40,41]. This bolsters the efficacy of the innate immune system by increasing phagocyte activity and the oxidative burst potential of macrophages and generating antimicrobial peptides that directly kill pathogens such as bacteria [42]. Thus, vitamin D deficiency has potential biologic consequences related to increased susceptibility to respiratory infection.

One important product of the vitamin D receptor pathway is cathelicidin, a microbicidal peptide targeting intracellular pathogens such as M. tuberculosis. When serum levels of vitamin D are inadequate, usually defined as <20 ng/mL, macrophage-initiated innate immune response to M. tuberculosis is impaired, leading to an increased risk of contracting tuberculosis [43,44]. Similar findings have been reported for other upper and lower respiratory tract infections such as community-acquired pneumonia and respiratory

syncytial virus (RSV), with lower levels of vitamin D being associated with an increased risk of infection [45–51]. When used for the treatment of influenza A H1N1, vitamin D was not found to alter viral replication or clearance, but in vitro treatment with vitamin D has been shown to decrease the expression of proinflammatory cytokines that often lead to severe complications such as pulmonary edema [52]. These findings have also been shown in RSV [53].

Vitamin D also has a non-traditional regulatory role in inflammation via its influence on oxidative stress pathways via nuclear factor-erythroid-2-related factor 2 (Nrf2), which regulates the expression of genes encoding antioxidant enzymes, apoptosis, inflammation, endothelial dysfunction, and cellular immunity [54,55]. Nrf2 activates the antioxidant response element (ARE), and activation of the ARE downregulates redox-sensitive and inflammatory genes, including nuclear factor-kB (NF-kB) [56]. Increasing oxidative stress leads to increased inflammation, and vice versa, and this is part of a deleterious cycle leading to the over-production of both oxidative stress and inflammation and adverse clinical sequelae [57]. Vitamin D repletion can attenuate this vicious cycle and the associated oxidative stress and inflammation by increasing Nrf2 and activating ARE.

As a result of its immunomodulatory effects, vitamin D has emerged as a micronutrient of interest in the prevention and care of patients with COVID-19 [58]. Observational studies have found associations with low levels of circulating 25-OH D, defined as <20 ng/mL, and higher test positivity rates for COVID-19 [59]. Large metropolitan residences and air pollution have both been independently associated with lower vitamin D levels, and it remains unclear if the association between vitamin D levels and risk of COVID-19 is also mediated by other socio-structural determinants of health including limited sunlight exposure and tropospheric ozone, an air pollutant with highly reactive oxidant properties [60,61]. The complicated downstream effect of the tree canopy, which only covers about 20% of LA County [21], may also play an important role; while the tree canopy allows for individuals to spend a greater time outdoors [62], it also decreases ultraviolet light and, in theory, may also reduce the subsequent production of vitamin D from pre-vitamin D in the skin.

As noted above, the suggestions regarding the benefits of vitamin D supplementation arise mainly from a large body of observational outcomes linking low 25-OH D levels with specific conditions, and more rigorous designs are awaited, such as Mendelian randomization studies that minimize confounding due to physical activity, outdoor exposure, diet, and other health habits and thereby advance implied causality. Clinical trials to date have not shown evidence for the benefits of the use of supplementation of vitamin D in patients with moderate-to-severe COVID-19 [63]. More well-designed, randomized controlled trials will be needed to further understand the role of vitamin D in the prevention and treatment of COVID-19 and the extent to which vitamin D might improve upon existing evidence-based interventions. It is important to note the risk of vitamin D deficiency during the pandemic was likely amplified by food insufficiency as well as the requirement to shelter at home and the wearing of face masks, both reducing exposure to sunlight and the conversion of pre-vitamin D to vitamin D [36]. It seems prudent that if vitamin D levels are assessed and determined to be low, 25-OH D supplementation (cholecalciferol or ergocalciferol) should be initiated with target serum levels maintained at 20 ng/mL or more as recommended by the IOM, or at 30 ng/mL or more as recommended by the Endocrine Society, recognizing that higher levels may be helpful in the setting of active comorbidities and likely co-existent micronutrient deficiency.

2.2. Vitamin A

Vitamin A, also known as retinoic acid or retinol, is another fat-soluble micronutrient, found within dairy products, liver, fish, and fortified cereals as well as various fruits and vegetables. Although vitamin A deficiency is prevalent throughout the world, it is not as common in the United States and occurs in <1% of adults. Individuals who suffer from malabsorption, such as those with histories of alcohol abuse or those with cystic fibrosis are at particularly high risk of vitamin A deficiency [64,65].

Vitamin A is best known for its role in vision and the prevention of night blindness. However, it also plays a key role in the immune system, helping to regulate the proliferation and differentiation of B and T cells. Within the lungs, it is important in maintaining epithelial integrity and the formation of lung alveoli [66].

Low retinoic acid levels have been found in other respiratory viral infections such as measles and RSV [67,68]. In the US, illness severity in measles has been associated with the degree of vitamin A deficiency [67]. As a result, the American Academy of Pediatrics and World Health Organization recommend vitamin A supplementation for patients hospitalized with measles [69].

While there are no studies to date that examine vitamin A levels and COVID-19, several hypotheses have emerged regarding the role of vitamin A in COVID-19. Interleukin-6 has been implicated as the one of the main cytokines contributing to disease severity in COVID-19 infection [70]. Vitamin A has been shown to attenuate cytokine release and inflammatory responses in other autoimmune conditions such as rheumatoid arthritis [71].

It has been hypothesized that decreased levels of vitamin A could be responsible, in part, for the immune dysfunction seen in COVID-19. COVID-19 RNA is broken down by the retinoic acid-inducible gene-I (RIG-I) pathway, which is dependent on vitamin A [72]. Due to the large size of the genome, high viral loads may overwhelm the RIG-I pathway, depleting stores of vitamin A in the body. It is possible that once this pathway no longer functions, the immune system shifts to a retinol-independent cytokine release making way for the cytokine release syndrome seen in COVID-19 [73].

In other systemic inflammatory reactions such as sepsis, patients have been found to have decreased levels of vitamin A [74]. More studies are needed to evaluate the role of vitamin A in the treatment of COVID-19 given its excellent safety profile, low cost, and widespread availability. While there are side effects related to hypervitaminosis A such as hepatotoxicity, pseudotumor cerebri, and rarely death, these are seen following the administration of much higher doses (>660,000 IU) than those that would be used for treatment or prevention [65,75].

2.3. Vitamin C

Vitamin C is an essential water-soluble vitamin obtained through the diet in fruits and vegetables and serves an important role in connective tissue and bone health. Deficiency is diagnosed clinically through skin and gingival signs including poor wound healing, gum bleeding, coiled hair, and perifollicular hemorrhage [76]. It can also be diagnosed with plasma levels < 0.2 mg/dl [76]. The prevalence of vitamin C deficiency varies greatly across the globe, from 74% in North India to 7.1% in the US [77]. While an inadequate diet plays a large role in deficiency, individuals who smoke or those with malabsorptive diseases are more susceptible to vitamin C deficiency [76].

As an antioxidant, vitamin C plays a role in the immune system protecting against oxidative stress due to infections and in the adrenocortical stress response enhancing cortisol release and downstream anti-inflammatory effects [78]. While a Cochrane review conducted by Hemilä et al. in 2013 found that vitamin C supplementation did not appear to decrease the incidence of the common colds in the general population, there was evidence that vitamin C intake decreased the incidence of colds in individuals under heavy short-term physical activity [79]. Given that vitamin C levels in white blood cells are decreased in the common cold [80], supplemental vitamin C during periods of increased oxidative stress such as strenuous physical activity may provide benefits. In trials with regular oral administration of vitamin C, cold duration decreased with an apparent dose dependency up to 6–8 g/day [81]. For sepsis and severe acute respiratory failure, the CITRIS-ALI trial investigated the use of intravenous vitamin C and found decreased mortality during the four-day administration of vitamin C [82,83]. Drawing from this trial, randomized control trials are currently studying the role of vitamin C in COVID-19 [78], with a pilot randomized trial in Wuhan showing decreased 28-day mortality (18% versus 50%) with high-dose vitamin C (12 g every 12 h for 7 days) [84].

For individuals at high risk for COVID-19 mortality and vitamin C deficiency, supplementation with vitamin C can be considered. Excessive vitamin C usually causes diarrhea and other gastrointestinal symptoms, as excess vitamin C acts as an osmotic agent [76]. There is a risk that increased long-term vitamin C intake could lead to iron overload and liver damage, but this is unlikely [76]. In severe COVID-19, vitamin C may be used as adjunctive treatment pending further data from these trials given its safety profile and low cost. It is important to note that more individuals may be at risk for vitamin C deficiency due to increased food insecurity as well as behavioral changes leading to decreased fruit and vegetable consumption [85].

2.4. Zinc

Zinc is an essential part of the immune system, aiding in the development and function of B and T cells and the innate immune system [86]. Zinc is also an antioxidant that helps stabilize membranes to prevent injury during the inflammatory process [87].

The side effects and the lack of demonstrated clinical benefit have limited its utility to date. In reviews of zinc and respiratory infection, there was indirect evidence that zinc supplementation aided the prevention of upper and lower respiratory tract infections and decreased common cold duration [88,89]. However, a recent small, randomized control trial did not demonstrate a significant difference among non-hospitalized patients receiving zinc or vitamin C supplementation [86]. Additionally, long-term supplementation has been shown to cause copper deficiency, resulting in hematologic and neurologic complications [88]. Therefore, the use of zinc is not recommended in the treatment or prevention of COVID-19 [90].

3. Intersection of Obesity and Micronutrient Deficiencies

As a state of chronic inflammation that leads to immune system and organ dysfunction, obesity has been documented as a major risk factor for COVID-19 morbidity and mortality. Obesity is attributed to excess caloric intake in obesogenic diets. Despite the excess calorie intake, obese individuals have a relatively high incidence of deficiency and insufficiency of several micronutrients, a phenomenon particularly prevalent in those with class III obesity, defined as having a BMI of 40 kg/m^2 or greater [91].

Obese individuals are more likely to have lower serum 25-OH vitamin D levels, as this fat-soluble hormone partitions into body fat. Reduced 25-OH vitamin D levels have been observed in 40% to 80% of obese individuals in survey studies [92–95]. Free 25-OH vitamin D and 1,25-$(OH)_2$ vitamin D have also been observed to be lower in obesity, with serum 25-OH vitamin D approximately 20% lower in obese people than in normal weight individuals [96,97].

Similarly, obese individuals may develop functional deficiencies in vitamin A with increasing adiposity. While the serum levels of vitamin A levels may be adequate, the severity of fatty liver disease was found to correlate with reductions in hepatic vitamin A levels and subsequent dysfunction in vitamin A-dependent pathways and cell signaling [98]. This "silent" vitamin A deficiency may augment susceptibility to respiratory infection, potentially leading to worse outcomes.

Moreover, vitamin C is inversely related to BMI, with obese individuals having lower levels of vitamin C [99]. While diet may play a role in lower levels of vitamin C, supplementation studies have shown that individuals of higher body weight have an attenuated response to vitamin C supplementation [100,101].

There is no clear consensus, and it remains uncertain whether the association is causal and, if so, the direction of causality. Several hypotheses have emerged describing obesity's role in perpetuating micronutrient deficiency and insufficiency, including increased needs in relation to body size, decreased absorption, altered metabolism as a result of an underlying low-grade inflammatory processes, and sequestration within adipose tissue [102].

4. Discussion

With the focus on food insecurity and its sequalae during this pandemic, micronutrient deficiency should also be given as much consideration as metabolic complications. Chronic conditions linked to food insecurity, including diabetes, hypertension, chronic kidney and pulmonary diseases, high cholesterol, and even depression, are associated with increased oxidative stress and immune dysregulation, which may be worsened in the presence of obesity and micronutrient deficiency [103,104]. As noted earlier, obesity may also be associated with increased risk of COVID-19 infection and complications due to its role in mediating a pro-inflammatory state, which can lead to sub-optimal immune responses via immune system dysregulation [7]. An array of inflammatory cytokines are increased in obese tissues, such as tumor necrosis factor alpha (TNF-α), C-reactive protein (CRP), plasminogen activator inhibitor-1 (PAI-1), interleukin (IL)-6, IL-1β, CCL2, and Toll-like receptors (TLRs) of the innate immune system, which may have additional implications in responses to vaccination and viral infections [105,106]. The activation of IL-1β and IL-6 in COVID-19 has been associated with "cytokine storms", which can have severe biological and clinical consequences [106].

Obesity may attenuate B- and T-cell responses, leading to both a decreased vaccination efficacy and a delay in viral resolution in infected patients. This may be due to an obesity-related hyperinflammatory state. Indeed, in obese mice, the amplification of the hyperinflammatory state by a high-fat diet led to an attenuation of vaccine-induced memory T-cell and neutralizing antibody production, as well as a more severe clinical course when exposed to the H1N1 influenza virus than non-obese mice or obese mice fed with a regular diet [107,108]. It remains unclear if obesity itself or diets rich in fat but depleted in micronutrients accounted for both outcomes. A similar clinical profile of a weakened adaptive immune response has been documented in COVID-19 patients with obesity and type 2 diabetes mellitus, supporting concerns for increased clinical risk [109,110]. This further was highlighted by Pellini et al. who found that overweight healthcare workers had significantly lower antibody titers 21 days following COVID-19 vaccination than their non-overweight peers, providing additional evidence of a potential reduction in vaccination efficacy, although the downstream clinical implications are not yet known [111].

Besides the activation of inflammatory cytokines and signaling factors, there are several additional pathways through which obesity may influence risk of COVID-19 infection and complications. The sequelae of being overweight and obese including metabolic, respiratory, cardiovascular, and thrombotic disorders may not only increase a patient's risk of COVID-19 infection but also COVID-19 complications by impairing the body's ability to cope with the initial infection [7,112]. Obesity can have a significant clinical impact due to structural changes in the body that can lead to a reduction in cardiorespiratory reserve (e.g., decreased expiratory reserve volume and functional residual capacity), thereby decreasing cardiorespiratory fitness and increasing susceptibility to immune-driven vascular and thrombotic effects [112].

Moreover, lockdown and the promotion of isolation during the pandemic have resulted in changes in dietary patterns, with people snacking more and choosing foods with lower nutritional value [85]. In overweight and obese individuals, disruptive eating behaviors have increased [113]. Coupled with the significant increase in people experiencing food insecurity, these dietary behaviors have led to an increased consumption of nutritionally deficient diets over the past year.

Los Angeles County (LAC) has over 10 million residents (more than 42 states) and is often considered an exemplar of nation health trends and profiles. In LAC, more than 1.9 million people are newly food insecure due to the consequences of COVID-19 [22]. It is estimated that in 2020, LAC had 6.2 million people living in food-insecure households, the highest number within the US [22]. South, Central, and East Los Angeles are also known food deserts, where residents' opportunities to choose and sustain healthier diets are limited by access to healthier food services [114,115]. In South Los Angeles, around 94% of food retail stores are corner and convenience stores [115]. Minority populations

are disproportionately affected, with over 76% of LAC's Latino/a population living in these areas [116]. Additionally, they make up over two-thirds of the county's food-insecure households [117]. Geographically, these areas have also been found to be clusters of high positivity rates for COVID-19 [118]. The effects of structural racism are apparent in the higher test positivity in those of Latino/a race/ethnicity, with the disproportionate contribution of the Latino/a population to the essential job sector from healthcare to grocery stores, as well as household density, poverty, and lower levels of educational attainment [118]. These are the same risk factors for food insecurity. In a survey conducted by the LA Department of Public Health, over 70% of food insecure adults did not have a bachelor's degree and over half of food insecure adults were unemployed or not in the labor force [117]. The risk factors that predispose individuals to infectious diseases and food insecurity overlap, intertwined within the lived experiences of those affected. As COVID-19 has shown, food insecurity and poverty set the stage for illness, which further perpetuates barriers of social mobility, unemployment, and deferring or forgoing education due to financial hardship.

Currently, the COVID-19 pandemic has highlighted the intersection and potential devastation of malnutrition including overweight, obesity, and micronutrient deficiency and viral respiratory disorders even in the US, a well-resourced country. Our emerging understanding of cardiometabolic disease in general and overweight/obesity being compounded by micronutrient deficiency as major risk factors for COVID-19 infection, hospitalization, and death has led to a better understanding of the pathophysiology of COVID-19 infections and important public health messaging to address COVID-19 across the nation. Unfortunately, the burden of overweight/obesity and micronutrient deficiency falls disproportionately on low-income populations and predominately racial and ethnic minorities, and the increased rates of COVID 19 infections, hospitalizations, and deaths among marginalized communities mirror the epidemiology of the increased rates of COVID-19 infections, hospitalizations, and deaths noted in patients who are overweight/obese. Educational efforts addressing poor dietary intake, overweight and obesity, and now also vaccination to reduce the risk of COVID-19 infections and its complications have met resistance related to intense counter-messaging that influences behavioral choices and that are not in an individual's best interest. Ongoing community-level efforts addressing both overweight and obesity and COVID-19 need to be pursued and reinforced while ensuring that respectful yet accurate messaging reaches the communities in greatest need [20,105,106].

The limitations of this study include the paucity of long-term randomized trials regarding micronutrients in patients with COVID-19 and obesity. In addition, the role of micronutrient deficiency in acute infections such as COVID-19 is difficult to ascribe to a given vitamin or nutrient due to their interdependence, limiting the assignment of risk and treatment recommendation based on RCT. However, given their high safety profile and low cost and intimate involvement in the inflammatory and immune processes, the recommendation for their supplementation to normal levels seems prudent. The emerging evidence points to the overweight/obesity proinflammatory state as a major factor leading to the attenuation of the normal activation of the immune system in COVID-19 patients, resulting in worse outcomes. As efforts to increase vaccine uptake continue, it is important to reinforce the message that overweight/obesity and resultant micronutrient deficiencies are important risk factors, and research studies need to continue to monitor the COVID-19 vaccine immune response in high-risk populations including those with overweight/obesity and micronutrient deficiency, and to recognize that this clinical profile is even more common in low-income and racial and ethnic minority groups. This monitoring should include checking for early clinical signs of COVID-19 in overweight/obese persons so that early intervention can be promptly managed [7]. Close attention to micronutrient deficiency is also warranted. From maintaining the respiratory epithelial barrier to ensuring proper signaling in the immune response, micronutrient deficiency may be associated with worse outcomes in COVID-19 and other respiratory infections. Such undervalued consequences

of food insecurity and, more specifically, the intake of poor-quality food and micronutrient deficiency in the context of obesity, warrant further exploration.

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Article

Physical Activity Behaviors and Physical Work Capacity in University Students during the COVID-19 Pandemic

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Abstract: *Objective*. The COVID-19 pandemic led to restricted access to sports and recreation facilities, resulting in a general decrease in physical activity. Many studies present the results of on-line questionnaires conducted during the pandemic, but there are few reports of objectively measured indicators of physical condition. Thus, the objective of this study was to assess the changes in physical work capacity, body composition, and physical activity behaviors in university students during 14 weeks of lockdown. *Material and Methods*. Twenty students of Tourism and Recreation (13 female and 7 male) participated in the study. The first examination was conducted in November 2020, and the second in March 2021. Body composition was assessed with a Tanita 418 MA device. The students performed the PWC 170 cycling test and completed the International Physical Activity Questionnaire (short version) on-line. *Results*. Neither physical work capacity nor body composition parameters changed substantially during the analyzed period. In the female students, vigorous physical activity decreased significantly, but no substantial changes occurred in weekly metabolic equivalent of task. In male students, walking days and metabolic equivalent of task decreased, but the changes were not significant. *Conclusions*. Fourteen weeks of COVID-19 lockdown had little effect on the body composition, physical work capacity level, and physical activity habits of Tourism and Recreation students. Studies with larger groups of participants should verify the current conclusions, and care should be taken when extrapolating to other populations.

Keywords: physical activity; body composition; PWC170; COVID-19; students

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1. Introduction

The benefits of physical activity and its effects on human health and well-being have been well researched by scientists and extensively documented [1–6]. A lack of physical activity is a risk factor for many diseases, which is of great importance from a public health point of view [7–10]. The global cost of physical inactivity in 2013 was estimated to be 54 billion international dollars (INT$) per year in direct health care, with an additional INT$ 14 billion in lost productivity. Inactivity accounts for 1–3% of national health care costs, although this excludes costs associated with mental health and musculoskeletal conditions [11].

In accordance with WHO recommendations, adults aged 18–64 years should do at least 150–300 min of moderate intensity aerobic physical activity per week, or at least 75–150 min of vigorous intensity aerobic physical activity, or an equivalent combination of moderate and vigorous intensity activity [11]. However, despite the promotion of physical activity and widespread access to knowledge about healthy lifestyles, 1 in 4 adults worldwide currently do not meet the global physical activity recommendations set by the WHO [12].

Adults also include university students, who can be considered a special social group. The transition from secondary to tertiary education is considered critical because this is often when, from a public health perspective, young people's behavior and lifestyle

change dramatically for the worse [13]. This change is associated with, among other things, poor eating habits and a reduction in the amount of physical activity performed by young people [14,15]. Unfortunately, the physical activity level of young people studying in higher education is too low [16,17].

The coronavirus pandemic has affected the physical activity of people all over the world. During the first wave, sports and recreational facilities were closed in many countries (e.g., swimming pools, gyms, fitness clubs, playgrounds) and organized physical activities were canceled. There were also limited opportunities for outdoor sports and recreation. For example, during the first lockdown in Poland, golf courses and hiking trails could not be used, and forest areas were excluded from recreational and tourist use, further limiting opportunities to be physically active. During the second wave of the pandemic, regulations were no longer as stringent, but many restrictions were maintained. Before the coronavirus pandemic, 65% of Poles declared that they were physically active at least once a month, and of these, 39% followed World Health Organization recommendations [18]. During the first lockdown, the number of physically active people fell by 4%, and during the second lockdown, it increased by 2% (to 63%) [19]. Similarly, research conducted around the world indicates that people's physical activity behavior changed over this period, and a large amount of recent research shows that, while most people decreased their involvement in physical activity, some increased it [20–22]. The situation of enforced confinement of millions of people to their homes and its impact on health in general, which has never been seen before in the modern world, will probably be analyzed by researchers for many years to come. However, many are already drawing attention to the particular importance of exercise in maintaining physical and mental health during lockdown, as well as mitigating the course and effects of COVID-19 [23,24]. Physical activity during lockdown/quarantine has also been encouraged by the World Health Organization, which has maintained its recommendations for physical activity [12].

The coronavirus pandemic was also not without its effects on the lifestyle of university students. The consequences of lockdowns included closure of universities, a shift to e-learning, and the closure of dormitories, which forced many students to return to their family homes. Like other citizens, students were deprived of access to sports and recreational facilities, but they were left with the option of continuing their physical activity at home, and, in many places, also outdoors. Therefore, from a research perspective, it was of interest whether this group of young adults took advantage of the limited opportunities to be physically active, and if so, to what extent. In our research, we focused on a group that (it is assumed) should be more active than most students in other fields of study: Tourism and Recreation students. This assumption reflects the fact that they have chosen a course of study in which physical recreation is an important part of education. The university curriculum includes many subjects (theoretical and practical) that prepare these students to be specialists in active forms of leisure and promoters of physical activity. Therefore, it is interesting to see whether they confirm the special importance of physical exercise for health (physical, mental, and social) by their own positive attitude towards it.

Thus, the objective of the study was to assess the changes in (i) physical work capacity, (ii) physical activity levels, and (iii) body composition in Polish university students during the so-called second wave of the COVID-19 pandemic.

2. Material and Methods

2.1. Design and Participants

The study began in November 2020, two weeks after the Polish government's decision to institute restrictions on public life due to the increase in the number of COVID-19 infections. University education was conducted exclusively by internet.

The targeted group consisted entirely of third-year students of Tourism and Recreation at the University of Warmia and Mazury in Olsztyn. The inclusion criteria included (i) a self-reported good state of health, (ii) no prior COVID-19 infection, and (iii) the ability to participate in laboratory examinations on the university campus. An invitation was sent to

67 Tourism and Recreation students using the Microsoft Office Teams communicator. All procedures were described in this invitation. Additionally, students were surveyed on-line about their personal experience with COVID-19. The students were asked to state if they had ever been infected with the SARS-CoV-2 virus or had been under quarantine because of co-residents' illness. Three students declared recovery from COVID-19 in the past four months and they were excluded from the study. Initially, 28 students who met the inclusion criteria agreed to participate in the study. Four students withdrew their participation shortly after this, and then four students decided not to participate for health or personal reasons. Thus, 13 female and 7 male students aged 21–24 years (mean 22.6 years) took part in the study. The anthropomorphic characteristics of the examined group are presented in Table 1. The students were asked not to change their eating habits during the study.

All of the procedures described below were conducted twice: in November 2020 and in February/March 2021. The period between the first and the second examination of each participant was 14 weeks ± 2 days. The participants were asked to refrain from alcohol, caffeine, energy drinks, and strenuous physical activity for 24 h prior to examination.

All measurements were conducted following appropriate procedures for safety during the pandemic. The measuring tools were treated with 70% alcohol before each measurement. The researchers and participants wore face masks (except for the PWC 170 test) and kept an appropriate distance from each other.

2.2. Data Collection

2.2.1. International Physical Activity Questionnaire

To assess the students' level of physical activity, the International Physical Activity Questionnaire (IPAQ) was employed. The short version of the questionnaire contains seven questions regarding the different kinds of physical activity performed in the last seven days. The respondent indicates how many days and how much time he/she devoted to vigorous physical activity, moderate physical activity, and walking. The metabolic equivalent of task (MET) is calculated based on the participant's responses to the questionnaire. The metabolic cost of vigorous activity is considered to be 8 MET/min; that of moderate activity, 4 MET/min; and that of brisk walking, 3.3 MET/min [25]. The respondents are then classified into three groups on the basis of their physical activity level [26]:

- Low physical activity—total physical activity of less than 600 MET/week;
- Moderate physical activity—total physical activity of more than 600 MET/week or vigorous physical activity of more than 480 MET/week;
- High physical activity—total physical activity of more than 3000 MET/week or vigorous physical activity of more than 1500 MET/week.

The questionnaire was sent to the participants via Microsoft Teams the day before examination in a laboratory. The students completed the questionnaire on-line and sent it back the same day.

2.2.2. Anthropomorphic Measurements

Anthropomorphic measurements were taken in the morning. The participants wore light sports clothes and were barefoot. Body height was determined to the nearest 0.1 cm with a Seca 216 stadiometer (Seca GmbH, Hamburg, Germany). Body composition was estimated using a Tanita BC 418 MA analyzer (Tanita Corp., Tokyo, Japan). Body composition measurements included body mass, body mass index, muscle mass, percentage of water, percentage of adipose tissue, visceral tissue, and basal metabolic rate. The measurements were taken twice, and the coefficient of variation was calculated for each pair of measurements: it ranged from 2.1 to 3.1.

Table 1. Measurements of Tourism and Recreation students during a 14-week period of the COVID-19 pandemic. Data is presented as mean value ± standard deviation.

	Body Height [cm]	**Body Mass [kg]**		**Body Mass Index [kg/m^2]**		**Body Fat [%]**		**Water [%]**		**Muscle Mass [kg]**		**Basal Metabolic Rate [kcal]**		**Visceral Tissue [Level]**	
		Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Females (n = 13)	166.3 ± 5.5	58.5 ± 9.7	58.6 ± 10.2	21.0 ± 2.6	21.0 ± 2.7	24.1 ± 6.6	24.1 ± 7.3	56.2 ± 5.0	56.3 ± 5.5	41.7 ± 4.6	41.6 ± 4.9	1360.6 ± 142.0	1351.8 ± 145.5	1.3 ± 0.6	1.4 ± 0.8
t-test p value		0.85		0.86		0.87		0.70		0.71		0.23		0.16	
Males (n = 7)	176.7 ± 7.9	69.0 ± 8.6	69.9 ± 9.4	22.1 ± 2.3	22.3 ± 2.5	17.2 ± 5.6	16.8 ± 5.7	59.1 ± 4.8	58.6 ± 5.4	53.5 ± 5.9	54.8 ± 6.0	1754.4 ± 166.9	1739.7 ± 167.3	2.1 ± 1.5	2.1 ± 1.8
t-test p value		0.06		0.18		0.80		0.55		0.14		0.15		1.0	

2.2.3. Physical Work Capacity 170 Test

The Physical Work Capacity 170 (PWC 170) test was used to estimate the subjects' work capacity at a heartrate of 170 beats per minute. The test was conducted on a Monark 874-E (Monark, Vansbro, Sweden) cycloergometer just after completing anthropomorphic measurements. Each participant adjusted the saddle of the cycloergometer to his/her body height. A Polar H10 heartrate monitor (Polar Electro, Kempele, Finland) was worn by the participants during the testing procedure. The test started with a one-minute cycling warm-up with a load of 30 W. Then the participant cycled constantly for 5 min with a load of 1 W per 1 kg of body mass. After one minute of rest, the participant cycled for another 5 min with a load of 1.5 W per 1 kg of body mass. The test finished after a one-minute cycling warm-down with a load of 30 W.

The result of the PWC 170 test was calculated using the following formula:

$$PWC170 = P1 + (P2 - P1) \times (170 - HR1)/(HR2 - HR1)$$

where P1 is the power (load) of the first effort, P2 is the power of the second effort, HR1 is heart rate during the first effort, and HR2 is heart rate during the second effort [27].

2.3. Statistics

Statistical calculations were performed using Statistica 12.0 (StatSoft, Tulsa, OK, USA). The Shapiro–Wilk test did not find significant deviations from normality. The results of the first (November 2020) and second (February/March 2021) measurements were compared using *t*-tests. Statistical significance was set at $p < 0.05$.

3. Results

Table 1 presents changes in the students' measurements over the 14-week period. The mean body mass of the male students increased slightly, and the basal metabolic rate of both female and male students decreased. However, the changes in these variables were not statistically significant. Interestingly, the values of body mass, body mass index, body fat, water content, and muscle mass remained almost unchanged in the female students.

Table 2 presents the results of the Physical Work Capacity 170 (PWC170) test. The work capacity, expressed in watts [W], increased slightly in both the female and male students, but the changes were not significant. The work capacity expressed in watts per kilogram of body mass [W/kg] did not change significantly in the analyzed period, either.

Table 2. Physical Work Capacity 170 test with Tourism and Recreation students during a 14-week period of the COVID-19 pandemic. Data are presented as mean value ± standard deviation.

	PWC170 [W]		**PWC170 [W/kg]**	
	Pre	**Post**	**Pre**	**Post**
Females (n = 13)	111.7 ± 26.1	118.0 ± 43.7	1.9 ± 0.3	2.0 ± 0.8
t-test p value	0.50		0.39	
Males (n = 7)	185.8 ± 69.7	186.9 ± 53.1	2.6 ± 1.0	2.6 ± 0.7
t-test p value	0.95		0.87	

Table 3 presents the changes in the students' physical activity (PA) levels based on their responses to the International Physical Activity Questionnaire (IPAQ). The time that female students devoted to vigorous physical activity decreased substantially. However, the time they spent on moderate physical activity, their walking time, and the energy they expended increased. In contrast, the male students increased the time they devoted to vigorous physical activity, although the change was not significant. The time they spent on moderate physical activity and their energy expenditure decreased. Overall, the smallest changes occurred in the number of days devoted to moderate physical activity, and in the

male students, this number remained unchanged. Additionally, the female students did not change the number of days devoted to walking.

Table 3. Physical activity levels in Tourism and Recreation students in a 14-week period of the COVID-19 pandemic. Data are presented as mean value ± standard deviation.

	Vigorous PA [Days]		Vigorous PA [min/day]		Moderate PA [Days]		Moderate PA [min/day]		Walking [Days]		Walking [min/day]		Total Metabolic Equivalent of Task [MET/week]	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Females (n = 13)	1.6 ± 1.3	1.1 ± 1.2	20.3 ± 17.6	16.1 ± 18.2	2.9 ± 1.1	3.0 ± 0.9	26.1 ± 16.2	30.7 ± 16.0	7	7	26.1 ± 8.9	35.3 ± 18.0	1370.3 ± 770.4	1486.9 ± 843.0
t-test p value	0.02		0.06		0.33		0.10		1.0		0.06		0.33	
Males (n = 7)	0.71 ± 1.1	0.85 ± 1.4	12.85 ± 17.0	17.14 ± 24.2	2.8 ± 1.5	2.8 ± 1.5	34.2 ± 26.9	25.7 ± 16.4	7	6.2 ± 1.2	45.7 ± 39.2	47.1 ± 22.1	1701.7 ± 1050.0	1633.5 ± 861.6
t-test p value	0.60		0.50		1.0		0.46		0.18		0.89		0.85	

4. Discussion

The objective of this study was to assess the potential changes in physical work capacity, body composition, and physical activity levels among Tourism and Recreation students during the COVID-19 pandemic. We hypothesized that restricted access to sports and recreation facilities would cause a decrease in their physical activity levels and physical work capacity. Our results indicate that, during the 14 weeks of lockdown in which the study took place, the students' metabolic equivalent of task (MET) changed very little. The MET of the female students slightly increased, whereas that of the male students slightly decreased, but neither of these changes was statistically significant. We did not examine the physical activity of the students before the pandemic; therefore, we cannot assess whether the PA of the students declined during the lockdown or not.

When comparing these results to those of other studies, it is important to remember the contexts in which the studies took place. In Poland, during the second wave of the COVID-19 pandemic, access to sports facilities, i.e., to swimming pools, sports halls, and fitness clubs, was limited only to competitive athletes. Moreover, typical winter outdoor recreation facilities like skate rinks and ski slopes were closed in accordance with government regulations. Thus, the effect of pandemic-related restrictions on people's physical activity may have depended on regional circumstances. For example, Sanudo et al. [28] reported that the PA levels of Spanish students decreased markedly during the first wave of the pandemic. However, it should be remembered that in Poland, and many other places, restrictions on public life were much more severe during the first wave than during the following waves of the pandemic. In Poland, during spring 2020, for example, going out of home was only allowed when visiting food shops, pharmacies, or commuting to work. It was not possible to participate in any outdoor or indoor sports or recreational activities because of the closed facilities. During the first wave of the pandemic, in Hungary, Acs et al. [29] did not detect substantial changes in the amounts of vigorous and moderate PA by Hungarian students surveyed online with IPAQ before and during the lockdown, but their weekly walking time decreased markedly. Chinese students also reported on-line that their level of PA decreased during the first wave of the pandemic in spring 2020, and more than 50% of those students did not meet the recommendations of the World Health Organization concerning the amount of physical activity [30]. As for Italian university students, there were significant decreases in their amounts of vigorous PA, moderate PA, and particularly in their amount of walking time during the pandemic [31]. A study of Italian medical students (female and male) also found substantially lower levels of PA during the lockdown than before it [32]. Interestingly, the mean total MET value of PA performed by the Italian medical students before the COVID-19 pandemic was almost equal to the mean total MET value of PA performed by the Polish Tourism and Recreation students during lockdown (1588 and 1538, respectively). The authors of the abovementioned Italian studies found that high levels of physical activity by the students before the pandemic were associated with higher physical activity levels during lockdown. However, Maltagliati et al. [33] found that subjects with previously strong PA habits demonstrated very low PA levels during the lockdown. Similarly, American students who were most physically active before the pandemic decreased their levels of PA substantially during lockdown [34]. Based on reports in the literature, we speculate that the Tourism and Recreation students in

our study might have reduced their PA levels after the COVID-19 pandemic began. Some studies have found that, before lockdown, Polish students in pro-health fields of study (e.g., physiotherapy, physical education, tourism and recreation) declared high levels of PA (2000–10,000 MET/week). The abovementioned studies were conducted with the IPAQ short-version scale, which means that the results are comparable with ours [35,36].

In our study, the 14-week period of the pandemic did not cause substantial changes in the physical work capacity of the Tourism and Recreation students. In both examinations, the female students' work capacity was classified as low, whereas that of the males was classified as average [37]. Kapilevich et al. [38] obtained similar results in the PWC170 test with male sports science students with low and average levels of extra-curricular physical activity. Studies conducted before the pandemic also reported similar values on the PWC 170 test for college-age women and men [39,40]. The lack of substantial changes in the work capacity of the examined students could be explained by their non-athlete status. Regular physical training raises the level of physical work capacity, but that level remains constant in non-athletes [41]. Moreover, non-athlete students and non-endurance athlete students usually display a lower level of physical work capacity than endurance sport students [42].

Our study did not find that the body composition of the Tourism and Recreation students changed significantly. The lack of substantial changes in their body composition may be due to two factors. First, their physical activity behaviors did not change during the study period. Second, our study was conducted for a relatively short period of time (14 weeks), and changes in their body composition may have been noticeable over a longer period. For example, Chwalczynska and Andrzejewski [43] reported significant changes in body composition between December 2019, i.e., four months before lockdown, and February 2021, during the so-called third wave of the pandemic. Body mass and body mass index increased in their male students, whereas fat mass increased in their female students. Similarly, Pop and Ciomag [44] took anthropometric measurements in Romanian students in spring 2018 and in December 2020, i.e., during the second wave of the pandemic, and found that their body mass index increased significantly in the analyzed period.

We realize that the number of participants is a limitation of our study. This number is due to the study being conducted during a period of remote learning without frequent direct contact with the students. Most of our Tourism and Recreation students lived outside our university town, and the student dormitories were closed. Therefore, some students did not accept our invitation to participate in the experiment because they did not have a place to stay. However, direct contact with the smaller group of students let us take objective measurements instead of only relying on subjective declarations of physical work capacity and body composition. This is a strength of our study, as such measurements were not common during that stage of the pandemic. Additionally, although the validity of the IPAQ short version examination in terms of metabolic equivalent of task (MET) determination is moderate, this questionnaire is used by national health institutions to assess the physical activity levels of large cohorts [45]. In any case, many of the results presented here should not be generalized because of local differences in sanitary restrictions. Instead, these results and those of similar studies provide an interesting basis for comparison.

5. Conclusions

The restricted access to sports and recreational activities during 14 weeks of the COVID-19 lockdown did not substantially influence the physical activity behaviors of Tourism and Recreation students. The physical work capacity of both the male and female students did not change significantly during this time, and no effect on their body composition was apparent. These conclusions should be confirmed with studies involving a greater number of participants and taking place in various locations.

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Informed Consent Statement: The participants were informed about the purpose and protocols of the study. All participants gave their informed consent.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

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Review

Will Nothing Be the Same Again?: Changes in Lifestyle during COVID-19 Pandemic and Consequences on Mental Health

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Abstract: Social isolation caused by the COVID-19 pandemic has drastically affected lifestyles: from sedentary behaviors to reduced physical activity, from disrupted sleep patterns to altered dietary habits. As a consequence, serious mental and emotional responses have been registered. There was a significant decline in physical and other meaningful activities of daily living, leisure, social activity, and education. In children, collateral effects of the pandemic include inadequate nutrition with a risk of both overweight and underweight, addiction to screens, lack of schooling, and psychosocial difficulties. Older adults are frequently unable to adapt to lockdown measures and suffer from depression and cognitive complaints. Recent studies focusing on changes in lifestyle during the Covid-19 pandemic and consequences on mental health have been identified in PubMed/Medline, Scopus, Embase, and ScienceDirect. All the available literature has been retrospectively reviewed. The results of the present narrative review suggest that mental distress caused by social isolation seems to be linked not only to personality characteristics but also to several lifestyle components (sleep disruption, altered eating habits, reduced physical activity). This review aims to explore major changes in the lifestyle and quality of life and the impact of these changes on mental health, and to inform clinicians and policymakers about elements that may reduce the negative psychological effects of the quarantine period imposed during this worldwide crisis. There is an urgent need for tailored preventive, diagnostic, and therapeutic mental health interventions for the general population and for higher risk groups.

Keywords: COVID-19; lifestyle; unhealthy habits; mental health; personalized medicine

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1. Introduction

The spread of the COVID-19 (SARS-CoV-2) pandemic all over the world has forced countries to handle the crisis in different ways, declaring a national state of alarm and establishing a mandatory home lockdown. The COVID-19 infection represents a strong stress stimulus, which has the capacity to induce high levels of perceived risk, fear, and anger, while forced quarantine at home may provoke an experience of boredom and loneliness, eliciting negative mental and behavioral responses in people [1]. It seems that the more time people remained at home, the more intense the resulting mental, emotional and lifestyle problems [2]. This situation has disrupted life and consequently altered multifaceted lifestyle behaviors. As a consequence, collateral damages of the

pandemic are represented by inadequate nutrition with a risk of both overweight or underweight, addiction to screens, social isolation, disrupted sleep, and reduced physical activity with increased sedentariness: all these indirect effects of the COVID-19 outbreak have a potential mental health impact, particularly for vulnerable groups, and require effective and targeted measures.

2. Methods

Studies focusing on changes in lifestyles during the COVID-19 pandemic and consequences on mental health were identified in PubMed/Medline, Scopus, Embase, and ScienceDirect. We searched cited databases for peer-reviewed publications related to the following keywords: "physical activity", "sedentary behavior", "sleep", "lifestyle behaviors", "COVID-19", "lockdown", "eating behavior", "mental health" on 1st July 2021. Inclusion criteria included original studies in peer reviewed journals focusing on changes in lifestyle behaviors during the COVID-19 pandemic and consequent lockdown. Eligible studies had to report data on habit changes during the pandemic and mental health. Both longitudinal and cross-sectional studies were admitted and could be retrospective or prospective. There were no time limits or language limits in regard to the selection of appropriate studies. Reviews or meta-analyses focusing on changes in lifestyle and possible preventive strategies have also been consulted. The latter were used to search among their references for further possible eligible studies. Studies were excluded if they did not focus on or were unrelated to the subject matter and if they were case reports or series. All authors participated in the selection of eligible studies to include in the present review.

3. Weight-Related Lifestyle Behaviors and the COVID-19

During the worldwide COVID-19 crisis and lockdown restrictions, behaviors that are health-protective against weight gain such as eating a healthy diet may be more difficult to achieve and maintain. A decrease in dietary diversification, with an aggravating effect of lockdown on disrupted consumption patterns, elevated symptoms of generalized anxiety disorder, decreased physical activity levels, and perceived weight gain have the effect of enhancing the risk of overweight and obesity [3]. More time at home may cause additional eating, along with sedentariness. Stress related to fear and the continuous bombardment of news by the media about the spread of the pandemic may push one to consume so-called "comfort foods" (mainly composed of sugar or fats) or bring about a greater consumption of snacks between meals, with a consequent heightened risk of developing obesity [4]. In a cross-sectional survey conducted in the United Kingdom, 79% of participants reported a decline of at least one of five weight gain protective lifestyle behaviors studied (eating healthy, bingeing on food, exercising, sleep, alcohol consumption). In particular, subjects with a diagnosis of psychiatric illness or obesity resulted in an increased risk of weight gain during the COVID-19 crisis [5]. A web-based survey conducted in France suggests that weight gain may also be interpreted as the result of the observed increase in addiction-related habits (caloric/salty food intake, screen use, substance use) during lockdown [6]. Similarly, a Spanish study observed a rise in emotional eating during the months of confinement, "food craving" (the desire to consume a specific kind of food), and eating to compensate for boredom or anxiety with an increase in weight [7]. People living with obesity and mental health problems may have an increased risk of showing lifestyle behaviors associated with weight gain during the COVID-19 crisis [5]. It has been outlined that during lockdown, a higher BMI (body mass index) was predictive of greater overeating and lower physical activity [8].

4. Reduced Physical Activity during Lockdown

Among abrupt societal changes related to the impact of COVID-19, there is a reduction of physical activity and prolonged sedentary behavior. Restrictions in physical activity were due to closed sport centers and limited social mobility. Social distancing and teleworking may contribute to sedentary lifestyles and an augmented sitting time

during the day, together with less time spent engaging in leisurely vigorous physical activity and total physical activity, unfavorable changes in motivation, and individual perceptions of fatigue [9]. It is well known that regular physical activity helps prevent several chronic medical conditions, such as diabetes, hypertension, cardiovascular diseases, cancer, chronic kidney diseases, obesity, and osteoarthritis. The other side of the coin is that a reduced physical activity leads to an increased body weight and risk of illness, including inflammatory and cardiometabolic diseases, with a consequent higher risk of contracting infectious diseases. Regular physical activity has also been demonstrated to potentially protect mental health and increase quality of life [10]. Maintaining and enhancing physical activity participation may mitigate depressive and anxiety symptoms associated with self-isolation/quarantine [11], because mental health and physical health are strongly associated and affected by each other. From such perspective, it has been noted that pregnant women who reported exercise changes during the pandemic exhibited significantly higher prenatal depression scores compared to those reporting no changes [12]. It seems that resilience may buffer the deleterious impact of quarantine on physical activity [13] and that exercise may lead to healthier nutritional choices (fruit, vegetables, fish) and mediate the effects of a deflected mood on unhealthy dietary habits [14]. In fact, there is evidence that older adults who regularly engaged in physical activity during the quarantine reported higher scores in resilience and positive affect and a lower incidence of depressive symptoms [15]. Besides, since there is an important correlation between sedentary behavior and low mood, the issue of reducing sedentary time during the period of social isolation may be stressed for beneficial effects during lockdown but also for future wellbeing [16]. People should be encouraged to maintain a moderate amount of physical activity during the quarantine, particularly women, who are usually less active than men [17]. Since COVID-19 women were less physically active than men and reported more barriers and fewer facilitators to physical activity, they experienced significantly more generalized anxiety than men and showed significantly lower mental health scores [18]. It has been observed that the restoration of physical activity through short-term interventions is not sufficient to improve mental health, so longer interventions are needed [19]. Since it has been demonstrated that maintaining or introducing an adequate level of physical activity is likely to mitigate detrimental effects of mental and physical problems related to the COVID-19 pandemic, promoting safe practice of physical activity in this difficult moment should represent a public health priority to promote better mental health and well-being [20,21].

5. Sleep Disruptions Due to COVID-19

Sleep disturbances have affected a great amount of people around the world during the COVID-19 pandemic lockdown. The loss of daily routines due to home confinement and the presence of change in work, family habits and financial concerns, the limited exposure to natural light, and reduced opportunities to exercise may have negative effects on sleep. Alterations in daily schedules have impacted circadian rhythms and energy balance with a significant repercussion of confinement on several external synchronizers of the biological clock [22]. More frequently observed sleep symptoms have been insomnia/disrupted sleep, daytime symptoms such as dozing off unintentionally in the day, difficulties falling/staying asleep, later bedtimes, abnormal behaviors in sleep, sleep-disordered breathing, restless legs, sleep phase disturbances, and nightmares [23]. Not only sleep quantity but also sleep quality was found to be compromised during the pandemic [24]. An Italian study found that more than half of the population had an impaired sleep quality and sleep habits during the COVID-19 lockdown; related risk factors for poor sleepers were female gender, living in Central Italy, loss of a close one because of COVID-19 infection, changed sleep-wake rhythms, elevated levels of stress, anxiety, and depression [25]. A study conducted in South Korea has demonstrated that the total time participants spent sleeping was significantly higher than that before the pandemic; nevertheless, since satisfaction with sleep decreased, they may have had a poor sleep quality [26]. Particularly, in students the increased use

of social media applications led to a significant delay in falling asleep, usually at much later hours than usual, a lengthening of the duration of sleep and a general feeling of tiredness [27]. A reported impact on mental health (depressive symptoms and anxiety) was most strongly associated with more difficulties falling asleep, sleep disruption, nightmares, and daytime sleepiness. It has been suggested that worsening sleep quality may partly mediate the association between sedentary behaviors (physical inactivity, high TV viewing, high computer/tablet use) and mental health indicators (loneliness, sadness, anxiety) [28].

6. Consequences of COVID-19 Lockdown on Lifestyle Behaviors of Children and Adolescents

The closure of schools due to lockdown has reduced possibilities for physical activities and social life. Children and adolescents have been deprived for a long time of educational environments, social activities, and consequently contact with peers, with a disruption of daily schedules and a significant reduction of affective, cognitive, and physical stimuli. Decreased organized physical activity, increase in sedentariness, screen time, and consumption of caloric and sugary food with a consequent higher susceptibility to weight gain may enhance the great problem of childhood obesity [29].

This situation represents a risk for the mental health of schoolchildren.

In preschoolers, one has observed during quarantine a reduction of sleep efficiency, an increase in internalizing (i.e., antisocial behaviors) or externalizing problems (i.e., anxious or depressed behaviors), and a reduction of the total physical activity [30], while it has been demonstrated that higher levels of physical activity were associated with an improvement of the mood state among children and adolescents in the pandemic [31]. There is also concern about the finding that long periods of free-movement restrictions may negatively affect cardiorespiratory fitness in children and adolescents, a critical hallmark of health in youth, measured through a delay during COVID-19 confinement of the normal development of VO_2 max (maximal oxygen uptake). High levels of VO_2 max in childhood and adolescence are associated with lower values of cardiovascular risk factors (waist circumference, blood pressure, total cholesterol, body mass index) and lower odds of metabolic syndrome in later life; therefore, it is essential for youths to achieve sufficient levels of physical activity to preserve reliable health indicators [32].

In a cross-sectional study investigating the prevalence of lifestyle habits and mental health problems in Chinese adolescents during the COVID-19 pandemic, it has been observed that better nutritional patterns and moderate physical activity were both associated with lower levels of depressive and anxiety symptoms, while highly active physical activity was associated with lower levels of insomnia, depressive, and anxiety symptoms [33].

Studies reporting the indirect effects of the COVID-19 pandemic on nutrition in children outline an increased consumption of junk food, snacking, and sweets, and a decreased consumption of fresh foods and eating in response to boredom or anxiety. There are concerns about the imminent risk of increased pediatric obesity in middle- and high-income countries, while undernutrition is expected to deepen in poor countries already affected by a humanitarian crisis [34]. During the COVID-19 pandemic, alerts have been issued regarding global food insecurity, described as concern about access to adequate and sufficient amounts of affordable and nutritious food. During the pandemic, a tendency has been observed to buy packaged and long-lasting foods rather than fresh foods. Among children and adolescents, food insecurity greatly impacts nutritional habits, often predisposing one to eating disorders or exacerbating eating pathology (binge eating disorder, bulimia nervosa, secretive eating, night-time eating) [35].

Sedentary behavior may have serious consequences on existing and emerging psychopathology in children and adolescents, as it has been counted among possible risk factors for the development of insomnia, depression, anxiety, and psychosis [36]. The potential mental health benefits of maintaining a positive affect, engaging in physical activity and limiting leisure screen time have been highlighted for children during the pandemic, particularly for children with overweight/obesity [37]. There are some promising strategies to combat sedentary behavior in youths, for example the organization of public

space options with individual physical distancing, exercise activities via live video conference calls, active-play video games that allow one to engage in indoor exercise activities, and above all adequate education for parents about the mental health benefits of regular activities [38]. A better understanding of students' behavioral and socializing changes during COVID-19 lockdown results in being pivotal to programing critical and effective strategies for managing children's mental health. Sleep and eating patterns, screen time, physical activity, and leisure seem to represent the most significant variables, influencing the many consequences of school closure and lockdown [39].

7. Discussion

A great amount of research agrees in affirming that the COVID-19 pandemic has had a negative impact on healthy and active lifestyles, with a contemporary and consequent decrease of mental health and quality of life.

It seems that individuals who have been involved in more physical activity and have adopted healthy lifestyle dietary and sleep rules had a better mental health and reached a better physical health status. Gender represents a predictor of mental health, since females seem to mentally adapt worse to confinement resulting from the COVID-19 pandemic [40]. Besides, prepandemic primary systems and specific emotion regulation may act as a protective or risk factor for mental and physical well-being during and after lockdown: specifically, pre-existing stable depressive symptoms may negatively influence the possibility of adopting healthier and more adaptive behaviors [41].

Unhealthy lifestyle behaviors observed in the pandemic period are inevitably related to the potential development of chronic diseases, but these behaviors also closely interact with the mental health of individuals. For example, physical limitation and ineffective weight management are frequently associated with stress, anxiety, and depression [42]. Some authors have suggested that dramatic changes in physical activity, sleep, eating behaviors, time use, and mental health have no precedents and that worldwide the COVID-19 crisis has inevitably tightened the link between lifestyle behaviors and depression [19]. Psychological and social symptoms elicited by lockdown and fear of contagion strongly condition the normal function of subjects and may significantly deteriorate daily life activities. In adolescence in particular, a critical period of life characterized by profound physiological developmental modifications that lead to adulthood, the adherence to healthy lifestyle habits is of the upmost importance to guarantee future health outcomes.

8. Conclusions

All studies considered in this review agree in outline that short- and long-term strategic plans regarding the problem of changes in lifestyle during the COVID-19 pandemic and consequences of these changes on the mental health of individuals are warranted. Information and interventions for individuals, communities, and healthcare institutions aimed at maintaining the healthiest lifestyle under quarantine should be guaranteed in order to prevent chronic diseases and psychiatric problems not only during the pandemic but also after the end of the outbreak, paying particular attention to children, adolescents, and at-risk groups (individuals with mental and/or physical health problems that existed before the spread of the COVID-19 pandemic, women, and older adults). For example, social media may play an important role in facilitating the self-management of behaviors related to physical activity, diet, and quality of life [43]. Besides, the rapid implementation of large-scale urban transformations may increase access to public open spaces and active transport infrastructure with the aim to promote physical activity and reduce sedentariness [44]. It has been suggested that there are different patterns of lifestyle changes for people all over the world during the COVID-19 pandemic, so there is a need to tailor support, interventions, and advice to different population groups [45], with the aim of providing appropriate strategies to rebuild balanced lifestyle patterns. As an indicator in the study, it also wants to highlight the importance of physical activity in promoting health

and mental health, following Goal 3 of the WHO 2030 agenda: health and well-being for all, and for all ages [46].

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Review

Physical Activity, Sedentary Behavior and Well-Being of Adults with Physical Disabilities and/or Chronic Diseases during the First Wave of the COVID-19 Pandemic: A Rapid Review

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Abstract: Background: People with physical disabilities and/or chronic diseases report lower levels of physical activity and well-being than the general population, which potentially is exacerbated through the COVID-19 pandemic. This study explored the international literature on physical activity, sedentary behavior and well-being in adults with physical disabilities and/or chronic diseases during the first wave of the pandemic. **Method:** In a rapid review, we included studies reporting on physical activity, sedentary behavior and/or well-being in adults with physical disabilities and/or chronic diseases. Four databases (Pubmed, CINAHL, PsycInfo, Embase) were searched for studies published until 30 September 2020. **Results:** We included twenty-nine studies involving eleven different types of disabilities or health conditions from twenty-one different countries. Twenty-six studies reported on physical activity, of which one reported an increase during the COVID-19 pandemic, four studies reported no difference, and twenty-one studies reported a decrease. Thirteen studies reported a decline in well-being. Only one study measured sedentary behavior, reporting an increase. **Conclusion:** Despite the variety in methods used, almost all studies reported negative impacts on physical activity and well-being in people with physical disabilities and/or chronic disease during the first wave of the pandemic. These findings highlight the importance of supporting this population, especially in times of crisis.

Keywords: coronavirus; rehabilitation; exercise; vulnerable populations; health

1. Introduction

In many developed countries, life expectancy has increased to over 80 years over the past century. At the same time, people have become increasingly physically inactive, leading to dramatic increases in lifestyle-related chronic diseases [1]. Recently, this was called the "*global pandemic of physical inactivity*" [2]. The financial burden of this physical inactivity pandemic was estimated to be USD 68 billion worldwide [3].

According to the updated World Health Organization (WHO) physical activity guidelines, all adults, including adults with disabilities or chronic diseases, should be active for 150–300 min at moderate intensity or 75–150 min at vigorous intensity aerobic per week to receive health benefits and reduce health risks [4]. Any bodily movement produced by skeletal muscles that requires energy expenditure could be classified under physical

activity [4]. However, the majority of adults with disabilities do not meet these guidelines [5]. The WHO defined physical disabilities as "*an umbrella term for motor impairments, activity limitations and participation restrictions. It denotes the negative aspects of the interaction between an individual and that individual's contextual factors*" [6]. In comparison with adults without disabilities or diseases, adults with physical disabilities or chronic diseases (such as cardiovascular or respiratory diseases) are, on average, less physically active and more sedentary [5,7]. To illustrate, it has been reported that 47% of the people with disabilities are inactive compared with 26% of the people without disabilities [5].

This is alarming, as physical activity, including sports, exercise, leisure time physical activity and active transport, is associated with many health benefits for people with physical disabilities and/or chronic diseases [8]. Being physically active decreases the risk for all-cause mortality and the development of several chronic diseases, such as coronary heart disease, hypertension, several types of cancer, type 2 diabetes mellitus, Alzheimer's disease and dementia, in both adults without and with disabilities [5,9,10]. In people with physical disabilities, being physically active improves physical fitness, which results in maintenance of functional independence with ageing [11,12]. In people without disabilities, there is a strong association between sedentary behavior and the risk for mortality and developing chronic diseases, independent of physical activity level [13]. Sedentary behavior could be defined as "*any waking behavior characterized by an energy expenditure of 1.5 METs or lower while sitting, reclining or lying*" [4]. This specific association between sedentary behavior and health is not yet studied in people with physical disabilities. Furthermore, adequate physical activity positively affects self-reported well-being and mental health in people with physical disabilities, expressed as higher quality of life, lower anxiety and depression scores, a more positive body image and better self-appearance [14,15]. The WHO defined this well-being as "*the general term encompassing the total universe of human life domains, including physical, mental and social aspects, that make up what can be called a 'good life'*" [6]. Another benefit of sufficient physical activity is that it has a positive effect on the immune system, by retaining metabolic balance, decreasing inflammation and increasing the number of lymphocytes [16,17]. These effects of physical activity on the immune system may be of particular importance in times of a virus pandemic.

After the first cases of the novel corona-type virus, named COVID-19 or Sars-CoV-2, were reported in December 2019, the WHO named COVID-19 as a pandemic on 11 March 2020 [18]. As a result of the pandemic, many countries subsequently went into (partial) lockdown, to the extent that for several countries, even outdoor activity was restricted for periods of time, and people were confined to their home environments for exercise [19]. Due to the lockdown, many sports facilities closed, which made it difficult to be physically active. By staying home, people avoided social contact. The outbreak of COVID-19 and the resulting lockdown have been generally associated with social and physical isolation [20–23] and have been found to impact on training and exercise in exercisers ranging from recreational to elite level [19]. It is precisely this kind of isolation that we have to beware of in people with physical disabilities and/or chronic diseases. In comparison with their peers without disabilities or diseases, adults with physical disabilities or chronic diseases experience generally higher levels of social isolation and loneliness and a lower level of perceived social support and social connectedness, and many already did so before the pandemic [24,25].

People with physical disabilities experience more and different barriers towards physical activity than their peers without disabilities [8]. People without physical disabilities experience personal barriers as the most important barrier leading them to not engage in sport or physical activity, such as lack of motivation or time. People with physical disabilities experience both personal (e.g., impaired mobility, fatigue and pain) as well as environmental barriers (e.g., lack of possibilities, lack of accessibility and transport) [8,26,27]. It is not unlikely that these barriers have expanded during the first wave of the COVID-19 pandemic.

Therefore, we conducted a rapid review exploring physical activity, sedentary behavior and well-being during the first wave of the COVID-19 pandemic in people with physical disabilities and/or chronic diseases. The primary research question was:

1. What is reported in the international literature on physical activity behavior in adults with physical disabilities and/or chronic diseases during the first wave of COVID-19 pandemic? Secondary research questions were:
2. What is reported in the international literature on sedentary behavior in adults with physical disabilities and/or chronic diseases during the first wave of the COVID-19 pandemic?
3. What is reported in the international literature on well-being in people with physical disabilities and/or chronic diseases during the first wave of the COVID-19 pandemic?

2. Methods

2.1. Study Design

We conducted a rapid review because of the immediate relevance and need in the ongoing COVID-19 pandemic. A rapid review can be defined as "*a form of knowledge synthesis that accelerates the process of conducting a traditional systematic review through streamlining or omitting a variety of methods to produce evidence in a resource-efficient manner*" [28]. Our study methods and results were guided by and reported using the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines [29].

2.2. Search Strategy and Eligibility Criteria

Four health databases (Pubmed, CINAHL, PsycINFO, Embase) were searched for relevant studies published between 1 December 2019 and 30 September 2020. The search strategy included the following keywords: (1) terms related to COVID-19: "*COVID-19*" OR "*Sars-CoV-2*" OR "*Coronavirus*" OR "*Corona virus*" and (2) terms related to physical activity, sedentary behavior and well-being: "*Physical activity*" OR "*Sport*" OR "*Sports*" OR "*Exercise*" OR "*Exercising*" OR "*Physical training*" OR "*Physical performance*" OR "*Sedentary behavior*" OR "*Sitting activity*" OR "*Sedentary inactivity*" OR "*Well-being*" OR "*Wellness*" OR "*Wealth*" OR "*Welfare*". To capture a broad range of potentially relevant literature, we did not include terms related to the population group in our search strategy. Functions in the databases were used to search only in the titles and abstracts and to include only studies written in English. Table A1 in Appendix A outlines additional details of the search strategies for each database.

We included primary studies that reported on the impact of the COVID-19 pandemic on physical activity, sedentary behavior and/or well-being in adults with a physical disability and/or chronic diseases. To be included in this review, the study had to report primary data on changes in physical activity, sedentary behavior and/or well-being in adults with a physical disability and/or chronic disease. Studies about people without a disability or chronic disease or children/youth were excluded. We also excluded studies about people with a visual, intellectual, aural or psychological disability.

Table 1 presents further details on inclusion and exclusion criteria.

2.3. Data Screening

The reference manager EndNote (EndNote X9 3.3, Clarivate Analytics, 160 Blackfriars Road, London, UK) and Excel were used to export and manage the results. The guidelines of Bramer et al. [30] were followed to remove duplicates. Title/abstract and full text screening were conducted by the first author (DB). Any uncertainties about eligibility criteria were discussed during a meeting with other team members (KH, FH, FJH), and final decisions about inclusion/exclusion were made accordingly.

Table 1. Inclusion and exclusion criteria.

	Inclusion Criteria	Exclusion Criteria
General	- The study reports on the impact of the COVID-19 pandemic on physical activity, sedentary behavior, and/or well-being in adults (>18 years) with a physical disability and/or chronic diseases.	
Population	- The study is about people with a physical disability and/or chronic disease. Physical disability is defined here as "an umbrella term for motor impairments, activity limitations and participation restrictions. It denotes the negative aspects of the interaction between an individual and that individual's contextual factors" [6].	- The study is about people without a disability and/or chronic disease. - The study is about people with a visual, hearing, intellectual and/or psychological disability. - The study is about children and/or youth.
Intervention	- Not applicable	
Comparison	- The study compares the situation before the COVID-19 pandemic with the situation in the COVID-19 pandemic.	
Outcomes	- The study reports on the impact of COVID-19 pandemic on physical activity, sedentary behavior AND/OR well-being. - Physical activity is defined as "any bodily movement produced by skeletal muscles that requires energy expenditure" [4]. - Sedentary behavior is defined as "any waking behavior characterized by an energy expenditure of 1.5 METs or lower while sitting, reclining or lying" [4]. - Well-being is defined as "the general term encompassing the total universe of human life domains, including physical, mental and social aspects, that make up what can be called a 'good life'" [6].	
Study design	- The study is a primary data study (e.g., cross-sectional, randomized controlled trials, observational etc.).	- The study is an integrative method (e.g., reviews, meta-analysis, editorials, commentary etc.).
Other	- The study is published between 1 December 2019 and 30 September 2020. - The study is published in English.	- The study is published after 30 September 2020.

2.4. Data Extraction and Analyses

Data extraction was done by two team members (DB or KH) using Excel. The following data were extracted from the included studies: authors, year of publication, study design, study population, participant information (disability/ health condition, age, gender), physical activity/sedentary behavior/well-being construct, measures (e.g., questionnaire or accelerometer), key results related to the impact on physical activity/sedentary behavior/well-being during the pandemic and direction of the impact (positive, negative, no change). Aligning with our research questions, the findings on physical activity were presented separately from the findings on sedentary behavior and well-being.

3. Results

The search strategy resulted in a total of 2931 articles identified from the four databases. After de-duplication, a total of 1174 unique articles remained. After screening of title and abstract, a total of 53 studies remained. From these 53 studies, 29 studies were included in this review after a full-text screening. Table A2 includes a list of excluded articles during full-text screening. Figure 1 presents a flowchart of the search procedure.

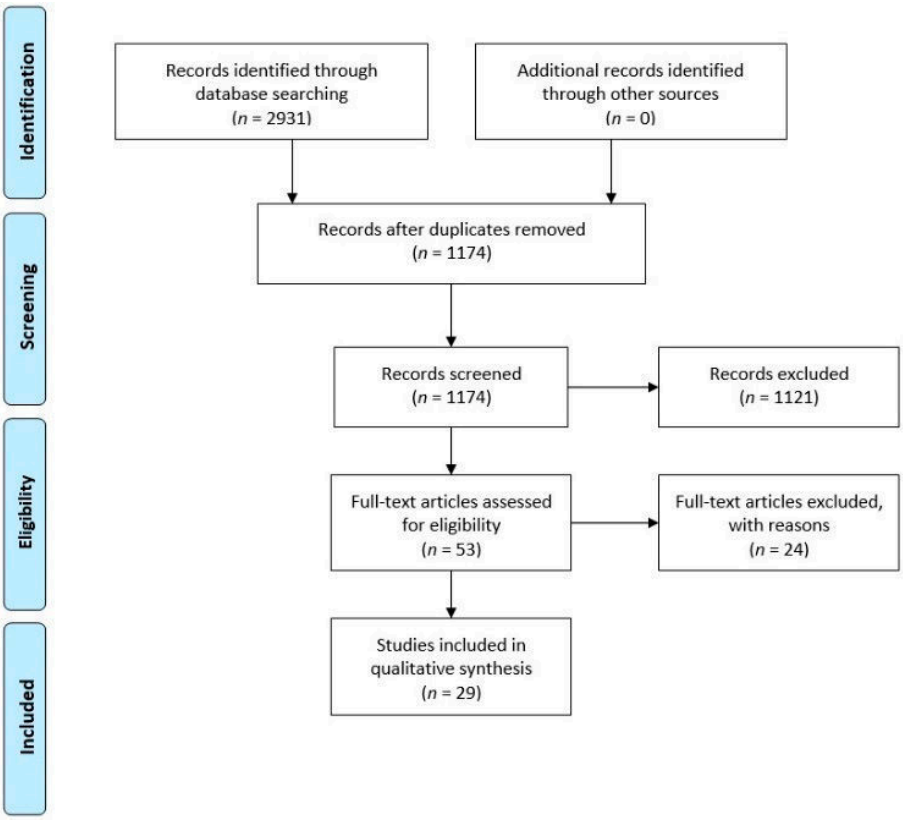

Figure 1. Flowchart of literature search.

The study characteristics are summarized and presented in Table 2. Twenty-one of the twenty-nine studies (72%) were cross-sectional studies (CS) [31–51], four studies (14%) were observational studies (OS) [52–55], and four studies (14%) were prospective cohort studies (PC) [56–59], whereas three were a prospective cohort study within an ongoing randomized clinical trial (PC-RCT) [57–59]. The studies were conducted in twenty-one different countries across four continents. Six studies (21%) were conducted in Italy [35,45,52,54,55,58], three (10%) in each of India [39,43,53] and the USA [33,48,58], two (6,9%) in each of Belgium [38,58], China [37,51], France [34,57] and the Netherlands [49,50] and one (3%) was conducted in each of Austria [56], Brazil [32], Canada [58], Czech Republic [59], Denmark [58], Egypt [46], Israel [36], Japan [40], Kuwait [31], Pakistan [44], South Korea [47], Spain [42], Switzerland [41], the UK [58] and one worldwide [33]. We included studies focusing on the following types of disabilities or health conditions: diabetes mellitus (n = 8; 28% [32,39,40,42,43,51–53]), Parkinson's disease (n = 5; 17% [33,45–47,50]), cardiovascular diseases (n = 5; 17% [34,54,55,57,59]), multiple chronic diseases (n = 3; 10% [36,44,48]), cystic fibrosis (n = 2; 7% [38,41]), osteoarthritis (n = 1; 3.4% [56]), multiple sclerosis (n = 1; 3.4% [58]), neuromuscular diseases (n = 1; 3% [35]), hereditary spastic paraplegia (n = 1; 3% [49]), skin diseases (n = 1; 3% [37]) and migraine (n = 1; 3% [31]). The number of participants ranged from 24 [55] to 9016 [51].

Table 2. The study characteristics of the included studies.

Author and Year	Country	Design	Type of Disability or Health Condition	Participants (n)	Age (Year) and Gender
Barone et al. (2020) [32]	Brazil	CS	Diabetes Mellitus	1701	Age: 18–30: 395, 30–40: 453, 40–50: 351, 50–60: 271, 60–70: 164, 70–80: 59, 80>: 8 Gender: M = 414, F = 1285
Khader et al. (2020) [39]	India	CS	Diabetes Mellitus	1510	Age: 41.6 Gender: M = 963, F = 543
Yan et al. (2020) [51]	China	CS	Diabetes Mellitus	9016 (DM: 585, no DM: 8431)	Age: 18–80 Gender: M = 3839, F = 5177
Assaloni et al. (2020) [52]	Italy	OS	Type 1 Diabetes Mellitus	154	Age: 44.8 ± 12.5 Gender: M = 84, F = 70
Khare et al. (2020) [53]	India	OS	Type 2 Diabetes Mellitus	143	Age: 54.68 ± 9.22 Gender: M = 91, F = 52
Munekawa et al. (2020) [40]	Japan	CS	Type 2 Diabetes Mellitus	203	Age: 67.4 ± 11.3 Gender: M = 126, F = 77
Ruiz-Roso et al. (2020) [42]	Spain	CS	Type 2 Diabetes Mellitus	72	Age: 63 (44–77) Gender: M = 35, F = 37
Sankar et al. (2020) [43]	India	CS	Type 2 Diabetes Mellitus	110	Age: 58.7 ± 10.8 Gender: M = 42, F = 68
Brown et al. (2020) [33]	USA/World	CS	Parkinson's disease (PD)	7209 (PD: 5429, No PD: 1780)	Age: 19–95 Gender: M = 3445, F = 3764
Schirinzi et al. (2020) [45]	Italy	CS	Parkinson's disease	74	Age: 61.3 ± 9.3 Gender: M = 37, F = 37
Shalash et al. (2020) [46]	Egypt	CS	Parkinson's disease	58 (PD: 38, No PD: 20)	Age: PD: 55.579 ± 9.956, No PD: 55.550 ± 5.708 Gender: M = 43, F = 15
Song et al. (2020) [47]	South Korea	CS	Parkinson's disease	100	Age: 70 (62.3–76.0) Gender: M = 54, F = 46
Van der Heide et al. (2020) [50]	The Netherlands	CS	Parkinson's disease	358	Age: 62.8 ± 9.0 Gender: M = 220, F = 138
Chagué et al. (2020) [57]	France	PC-RCT	Congestive heart failure	124	Age: 71.0 ± 4.0 Gender: M = 75, F = 49
Vetrovsky et al. (2020) [59]	Czech Republic	PC-RCT	Heart failure	26	Age: 58.8 ± 9.8 Gender: M = 18, F = 8
Malanchini et al. (2020) [54]	Italy	OS	Chronic cardiovascular disease	184	Age: 67 ± 14 Gender: M = 134, F = 50
Sassone et al. (2020) [55]	Italy	OS	Implantable cardioverter-defibrillators	24	Age: 72 ± 10 Gender: M = 17, F = 7
Cransac-Miet et al. (2020) [34]	France	CS	Chronic Coronary Syndromes	195	Age: 65.5 ± 11.1 Gender: M = 119, F = 76
Elran-Barak et al. (2020) [36]	Israel	CS	Chronic diseases	315	Age: 18–45: 60, 46–55: 43, 56–65: 69, 66–75: 107, 76>: 33 Gender: M = 121, F = 178
Saqib et al. (2020) [44]	Pakistan	CS	Chronic diseases	181	Age: 18–35: 75, 36–55: 52, 55>: 54 Gender: M = 109, F = 72

Table 2. *Cont.*

Author and Year	Country	Design	Type of Disability or Health Condition	Participants (n)	Age (Year) and Gender
Umucu et al. (2020) [48]	USA	CS	Self-reported disabilities and chronic conditions	269	Age: 39.37 ± 12.18 Gender: M = 151, F = 118
Havermans et al. (2020) [38]	Belgium	CS	Cystic Fibrosis	219	Age: 16–67 Gender: M = 86, F = 133
Radtke et al. (2020) [41]	Switzerland	CS	Cystic Fibrosis	327	Age: 72.5% <40, 27.5% >40 Gender: M = 171, F = 155
Chiaravalloti et al. (2020) [58]	Italy/UK/ Canada/ Denmark/ Belgium/USA	PC-RCT	Progressive Multiple Sclerosis	131	Age: 52,1 ± 9.6 Gender: M = 48, F = 83
Endstrasser et al. (2020) [56]	Austria	PC	Osteoarthritis	63	Age: 62.4 ± 11.84 Gender: M = 35, F = 28
Di Stefano et al. (2020) [35]	Italy	CS	Neuromuscular diseases	268 (NM: 149, No NM: 119)	Age: 57.3 ± 13.7 (NM) 56 ± 6.8 (no NM) Gender: M = 176, F = 92
Van de Venis et al. (2020) [49]	The Netherlands	CS	Hereditary spastic paraplegia	58	Age: 57 (range 30–77) Gender: M = 27, F = 31
Guo et al. (2020) [37]	China	CS	Skin diseases	506	Age: 33.5 ± 14.0 Gender: M = 217, F = 289
Al-Hashel et al. (2020) [31]	Kuwait	CS	Migraine	1018	Age: <20: 38, 20–40: 733, 40–60: 235, 60>: 12 Gender: M = 160, F = 858

Note: cross-sectional study, CS; observational study, OS; prospective cohort study within an ongoing randomized clinical trial, PC-RCT; prospective cohort study, PC; male, M; female, F.

3.1. Physical Activity (Primary Research Question)

Twenty-six studies (81%) reported findings about physical activity during the first wave of the COVID-19 pandemic [31–36,38–47,49–52,54–57,59]. These studies included 23,710 individuals with nine different types of disabilities or chronic diseases. One study (4%; 1 out of 26) including adults with diabetes [51] reported an increase in physical activity during the COVID-19 pandemic. Twenty-five studies (96%; 25 out of 26) reported no difference or a decrease in physical activity. The key findings regarding physical activity behavior during the pandemic are summarized in Table 3. A variety of physical activity constructs (e.g., daily physical activity, number of steps, moderate-intensity and vigorous-intensity activities) was used to assess physical activity. Twenty-three studies used self-reported measures and four used accelerometer-based measures. Across all included studies, constructs of physical activity were measured with thirteen different measures (see Table 4 for an overview, see Table S1 for a more detailed overview).

Table 3. Key findings regarding physical activity during the first wave of the COVID-19 pandemic.

Author and Year	Type of Disability or Health Condition	PA Construct	Method	Primary Results	Change in PA *
Barone et al. (2020) [32]	Diabetes Mellitus	Change in PA	5-Likert scale question	59.5% reported a decrease in PA.	–

Table 3. *Cont.*

Author and Year	Type of Disability or Health Condition	PA Construct	Method	Primary Results	Change in PA *
Khader et al. (2020) [39]	Diabetes Mellitus	Change in PA	3-Likert scale question	69.07% reported a decrease in PA.	–
Yan et al. (2020) [51]	Diabetes Mellitus	Changes in PA	International Physical Activity Questionnaire (IPAQ)	67.7% with diabetes (vs. 41.2% without diabetes) reported an increased level of PA.	+
Assaloni et al. (2020) [52]	Type 1 Diabetes Mellitus	Type of exercise Godin Scale Score Minutes of exercise Steps number	Godin-Leisure Time Exercise questionnaire (GLTEQ), Activity Tracker	Significant decrease in perceived and measured PA level.	–
khare et al. (2020) [53]	Type 2 Diabetes Mellitus	Change in type Change in timing Change in duration	2-Likert scale question	80.42% reported a change in type. 72.72% reported a change in timing. 60.84% reported a change in duration.	–
Munekawa et al. (2020) [40]	Type 2 Diabetes Mellitus	Change in exercise	Visual analogue scale (VAS)	53.69% reported a decrease in exercise level. Mean score of 3.7 (0: considerably reduced to 10: considerably increased)	–
Ruiz-Roso et al. (2020) [42]	Type 2 Diabetes Mellitus	Change in PA	IPAQ	Significant increase in the daily hours that the participants of the study were sitting without doing any PA at all. Significant decrease of the average minutes per week spent walking. Decline in the average weekly time spent doing any type of moderate physical activity.	–
Sankar et al. (2020) [43]	Type 2 Diabetes Mellitus	Change in PA	Face-to-face interview	82.7% reported no major change in PA.	
Brown et al. (2020) [33]	Parkinson's disease	Change in exercise	4-Likert scale question	21% reported a cancelled/disrupted exercise. 7.9% reported a postponed exercise. 41% reported an alternative conducted exercise. 30% not reported any changes in exercise.	–/*
Schirinzi et al. (2020) [45]	Parkinson's disease	Motor activity habits	International Physical Activity Questionnaire—Short Form (IPAQ-SF)	No change in total patients playing sports.	*

Table 3. *Cont.*

Author and Year	Type of Disability or Health Condition	PA Construct	Method	Primary Results	Change in PA *
Shalash et al. (2020) [46]	Parkinson's disease	Change in PA	IPAQ-SF, Parkinson's Disease questionnaire (PDQ39), 2-Likert scale COVID questions	Significant decline in physical activity. Compared with control group: significant worse moderate physical activity, walking and total IPAQ. 68.4% of the patients reported decline of PA.	–
Song et al. (2020) [47]	Parkinson's disease	Change in exercise (amount, duration and frequency)	Physical Activity Scale of the Elderly (PASE) questionnaire	Significant decrease in the amount of exercise.	–
Van der Heide et al. (2020) [50]	Parkinson's disease	Change in PA	5-Likert scale question	46.6% were physically less active.	–
Chagué et al. (2020) [57]	Congestive heart failure	Change in PA	Telephone interview	41.9% reported a decreased PA.	–
Vetrovsky et al. (2020) [59]	Heart failure	Daily number of steps	Wrist-worn accelerometer	16% decrease of daily step count.	–
Malanchini et al. (2020) [54]	Chronic cardiovascular disease	Activity level (h/day)	Implanted devices	Decrease in PA of 0.5 h per day, a decrease of more than 25% compared with the activity during the pre-lockdown period and reference period.	–
Sassone et al. (2020) [55]	Implantable cardioverter-defibrillators	Change in PA	Implantable cardioverter-defibrillator	Mean 25% reduction of PA was observed.	–
Cransac-Miet et al. (2020) [34]	Chronic Coronary Syndromes	Change in PA	Telephone interview	45% declared >25% reduction in PA.	–
Elran-Barak et al. (2020) [36]	Chronic diseases	Level of PA	Adapted Medical Outcomes Study-Short Form 36 items (SF-36 MOS)	Significant decrease in PA.	–
Saqib et al. (2020) [44]	Chronic diseases	Change in daily exercise	2-Likert scale question	66% could not continue their daily exercise.	–
Havermans et al. (2020) [38]	Cystic Fibrosis	Change in exercise	2-Likert scale (yes/no)	53.2% of the adult CF patients reported they were not exercising more.	–/*
Radtke et al. (2020) [41]	Cystic Fibrosis	Change in PA	VAS	44.8% reported decreased PA.	–
Endstrasser et al. (2020) [56]	Osteoarthritis	Change in daily activity	Tegner activity scale (TAS)	Significant decreased level of activity.	–
Di Stefano et al. (2020) [35]	Neuromuscular diseases	Total PA level MVPA level (moderate-intensity and vigorous-intensity)	IPAQ-SF (adapted version)	Significant reduction of PA was reported for walking activity, total PA level and MVPA level, while no difference was found for vigorous-intensity PA and moderate-intensity PA.	–

Table 3. *Cont.*

Van de Venis et al. (2020) [49]	Hereditary spastic paraplegia	Change in PA	5-Likert scale question	74% reported a reduction of PA.	–
Al-Hashel et al. (2020) [31]	Migraine	Level of exercise	2-Likert scale question	79.7% reported an increased lack of regular exercise.	–

Note: * Change in physical activity during the COVID-19 pandemic compared with before the pandemic. A positive change (+) indicates an increase in physical activity, no change (*) indicates no change in physical activity and a negative change (−) indicates a decrease in physical activity during the COVID-19 pandemic compared with before the start of the pandemic.

Table 4. Different physical activity measurements used in the included studies.

	Self-Reported Measurements								Accelerometry					
Author and Year	**LS**	**GLTEQ**	**IPAQ**	**IPAQ-SF**	**IV**	**PD Q39**	**PASE**	**SF-36 MOS**	**TAS**	**VAS**	**AT**	**ID**	**AM**	**Change in PA ***
Barone et al. (2020) [32]	✓													–
Khader et al. (2020) [39]	✓													–
Yan et al. (2020) [51]			✓											+
Assaloni et al. (2020) [52]		✓									✓			–
Khare et al. (2020) [53]	✓													–
Munekawa et al. (2020) [40]										✓				–
Ruiz-Roso et al. (2020) [42]			✓											–
Sankar et al. (2020) [43]					✓									*
Brown et al. (2020) [33]	✓													–/*
Schirinzi et al. (2020) [45]				✓										*
Shalash et al. (2020) [46]	✓			✓		✓								–
Song et al. (2020) [47]							✓							–
Van der Heide et al. (2020) [50]	✓													–
Chagué et al. (2020) [57]					✓									–
Vetrovs-ky et al. (2020) [59]													✓	–
Malanchini et al. (2020) [54]												✓		–
Sassone et al. (2020) [55]												✓		–
Cransac-Miet et al. (2020) [34]					✓									–
Elran-Barak et al. (2020) [36]								✓						–
Saqib et al. (2020) [44]	✓													–

Table 4. *Cont.*

	Self-Reported Measurements								Accelerometry					
Author and Year	**LS**	**GLTEQ**	**IPAQ**	**IPAQ-SF**	**IV**	**PD Q39**	**PASE**	**SF-36 MOS**	**TAS**	**VAS**	**AT**	**ID**	**AM**	**Change in PA ***
Havermans et al. (2020) [38]	✓													−/*
Radtke et al. (2020) [41]										✓				−
Endstrasser et al. (2020) [56]									✓					−
Di Stefa-no et al. (2020) [35]				✓										−
Van de Venis et al. (2020) [49]	✓													−
Al-Hashel et al. (2020) [31]	✓													−

Note: * Change in physical activity during the COVID-19 pandemic compared with before the pandemic. A positive change (+) indicates an increase in physical activity, no change (*) indicates no change in physical activity and a negative change (−) indicates a decrease in physical activity during the COVID-19 pandemic compared with before the start of the pandemic. Likert scale, LS; Godin-Leisure Time Exercise questionnaire, GLTEQ; International Physical Activity Questionnaire, IPAQ; International Physical Activity Questionnaire—Short Form, IPAQ-SF; Interview, IV; Parkinson's Disease questionnaire, PDQ39; Physical Activity Scale of the Elderly, PASE; Medical Outcomes Study-Short Form 36 items, SF-36 MOS; Tegner activity scale, TAS; Visual analogue scale, VAS; activity tracker, AT; implanted devices, ID; accelerometer, AM.

3.2. Sedentary Behavior and Well-Being (Secondary Research Questions)

Only one study [42] reported on changes in sedentary behavior during the first wave of the pandemic (see Table 3). This study reported that adults with type 2 Diabetes Mellitus in Spain increased sitting time during the COVID-19 pandemic compared with before the pandemic.

Thirteen of the included studies (45%) reported findings on changes in well-being during the pandemic [36–38,43–46,48–50,57,58]. These studies included 2466 individuals with nine different types of disabilities or health conditions. All thirteen studies reported a negative change in one or more constructs related to well-being of adults with physical disabilities or chronic diseases during the first wave of the COVID-19 pandemic. These findings are summarized in Table 5. Across the thirteen studies, nine different well-being constructs (anxiety, depression, loneliness, mental health, overall health, pain, quality of life, stress, well-being) were reported. Table 6 provides an overview of the well-being constructs.

Table 5. Key findings regarding well-being during the first wave of the COVID-19 pandemic.

Author and Year	Type of Disability or Health Condition	WB Constructs	Method	Primary Results	Change in Well-Being *
Sankar et al. (2020) [43]	Type 2 Diabetes Mellitus	Stress Anxiety	Hospital Anxiety and Depression Scale (HADS)	15.5% increased mental stress and higher anxiety levels.	−
Schirinzi et al. (2020) [45]	Parkinson's disease	Depression	Parkinson's Well-Being Map (PWBM), Beck Depression Index (BDI)	59.5% perception of worsening in global health during COVID. Worsening patients have a significant higher PWBM and BDI score.	−
Shalash et al. (2020) [46]	Parkinson's disease	Mental health Health care	Depression, Anxiety, and Stress scale-21 (DASS-21), PD questionnaire (PDQ39), 2-Likert scale COVID questions	Compared with control group: significant worse stress, depression, anxiety and total DASS. 52.6% reported anxiety/stress due to COVID-19.	−

Table 5. *Cont.*

Author and Year	Type of Disability or Health Condition	WB Constructs	Method	Primary Results	Change in Well-Being *
Van der Heide et al. (2020) [50]	Parkinson's disease	Perceived stress PD symptom severity Stressor load	DynaCORE-C, Perceived Stress Scale (PSS), Unified Parkinson's Disease Rating Scale part Ib and II (MDS-UPDRS-self), Parkinson Anxiety Scale (PAS), Ruminative Response Scale (RRS), List of external stressors	Higher levels of stress and anxiety.	–
Chagué et al. (2020) [57]	Congestive heart failure	Self-reported well-being Psychological distress Heart failure symptoms Health care access	Psychological distress –> Kessler 6 score (K6)	21.8% reported a decrease in well-being. 18.5% reported psychological distress. 21.8% reported an increase in health failure symptoms. Significant reduction in health care access.	–
Elran-Barak et al. (2020) [36]	Chronic diseases	(Change in) physical self-reported health (SRH) (Change in) mental physical self-reported health (SRH) Loneliness	Adapted Medical Outcomes Study-Short Form 36 items (SF-36 MOS)	47.2% reported decline in physical SRH. 14.6% reported a bad/very bad current physical SRH. 50.5% reported a decline in mental health. 14.2% reported a bad/very bad current mental health. Significant decline in level of loneliness.	–
Saqib et al. (2020) [44]	Chronic diseases	Self-reported overall health	2-Likert scale question	44.75% reported an effect on self-reported overall health.	–
Umucu et al. (2020) [48]	Self-reported disabilities and chronic conditions	Perceived stress Coping Well-being Depression and anxiety	Perceived stress questionnaire-8, Brief COPE, PERMA-Profiler, Patient Health Questionnaire-4	Small negative impact on well-being: moderate level of stress, depression and anxiety during the COVID pandemic.	–
Havermans et al. (2020) [38]	Cystic Fibrosis	Emotional well-being Changes in behavior or worries about CF	2-point Likert scale	Patients reported more sadness, discouragement, feelings of helplessness, perception of deterioration and difficulty with adhering to their routine.	–
Chiaravalloti et al. (2020) [58]	Progressive Multiple Sclerosis	Change in level of depression, anxiety, overall quality of life	COVID Impact survey HADS Beck Depression Inventory-II (BDI-II) Multiple Sclerosis Impact Scale EuroQol	Increased anxiety and depression. No difference in MS symptomatology. No significant difference on BDI-II. Significant increase in HADS-depression score, but no differences in HADS- anxiety scale or EQ5D scales.	–

Table 5. *Cont.*

Author and Year	Type of Disability or Health Condition	WB Constructs	Method	Primary Results	Change in Well-Being *
Endstrasser et al. (2020) [56]	Osteoarthritis	Change in pain and mental health	Visual analogue scale (VAS), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), Short-Form Health Survey (SF-12)	VAS and WOMAC scores increased significantly during lockdown. The mental health component remained largely unchanged.	–
Van de Venis et al. (2020) [49]	Hereditary spastic paraplegia	Change in psychological stress	5-Likert scale question	43% reported an increase in psychological stress.	–
Guo et al. (2020) [37]	Skin diseases	Perceived stress Anxiety Depression Quality of life	VAS, Perceived Stress Scale 14 item (PSS-14) Generalized Anxiety Disorder 7 item (GAD-7), Patient Health Questionnaire 9 item (PHQ-9), Dermatology Life Quality Index (DLQI)	Increased symptoms of anxiety and depression. Significant impaired mental well-being and quality of life.	–

Note: * Change in one or more constructs related to well-being. A negative change (−) indicates a decrease or decline in one or more well-being constructs during the COVID-19 pandemic compared with before the start of the pandemic. Well-being = WB.

Table 6. Different well-being constructs used in the included studies.

Author and Year	Anxiety	Depression	Loneliness	Mental Health	Overall Health	Pain	Quality of Life	Stress	Well-Being	Change in Well-Being
Sankar et al. (2020) [43]	✓							✓		–
Schirinzi et al. (2020) [45]		✓								–
Shalash et al. (2020) [46]				✓						–
Van der Heide et al. (2020) [50]								✓		–
Chagué et al. (2020) [57]								✓	✓	–
Elran-Barak et al. (2020) [36]			✓	✓						–
Saqib et al. (2020) [44]					✓					–
Umucu et al. (2020) [48]	✓	✓						✓	✓	–
Havermans et al. (2020) [38]		✓						✓	✓	–
Chiaravalloti et al. (2020) [58]	✓	✓								–
Endstrasser et al. (2020) [56]				✓		✓				–

Table 6. *Cont.*

Author and Year	Anxiety	Depression	Loneliness	Mental Health	Overall Health	Pain	Quality of Life	Stress	Well-Being	Change in Well-Being
Van de Venis et al. (2020) [49]								✓		–
Guo et al. (2020) [37]	✓	✓					✓	✓		–

Note: Change in one or more constructs related to well-being. A negative change (−) indicates a decrease or decline in one or more well-being constructs during the COVID-19 pandemic compared with before the start of the pandemic.

4. Discussion

This rapid review provides an overview of studies reporting on physical activity, sedentary behavior and well-being in people with physical disabilities and/or chronic diseases during the first wave of the COVID-19 pandemic. In the short time after the COVID-19 outbreak, we identified already twenty-nine studies including different types of physical disabilities and chronic diseases from twenty-two different countries on four different continents. Despite the large variation in study contexts and methodologies, almost all studies reported a negative impact on physical activity, sedentary behavior and well-being during the first wave of the COVID-19 pandemic.

4.1. Impact on Physical Activity during the COVID-19 Pandemic

Twenty-six studies reported on physical activity during the first wave of the pandemic. Almost all studies demonstrated a negative impact on the level of physical activity. This negative impact on physical activity is in accordance with a systematic review summarizing sixty-four articles on physical activity change during the first wave of COVID-19 in the general population [60]. An earlier rapid review, studying the broader impact of COVID-19 on health and participation also found a decrease of physical activity in people with neuromuscular disease and chronic pain [23]. This negative impact on physical activity can probably be explained by the many barriers regarding physical activity that people with (or without) physical disabilities may face [8]. Many of these influencing factors, such as social support, professional assistance, and availability of equipment and transportation, became less available in many countries due to lockdown restrictions, including the closing of sports facilities. It is important to note that this is a worldwide review and that lockdown restrictions varied between countries. People in some countries were obliged to stay home, while people in other countries were still able to be active outside, a finding that also came forward in the study by Washif et al. (under review) [19]. Although not studied, it is likely that the magnitude of impact of COVID-19 restrictions on physical activity, sedentary behavior and wellbeing, summarized in this rapid review, may be associated with the severity of lockdown restrictions.

Included studies in this review used a variety of methodologies (Table 3) and physical activity measures (Table 4). The majority of the studies assessed the self-reported difference in the degree of physical activity between the situation before the pandemic compared with the situation during lockdown. Many questionnaires were investigator-developed and/or non-validated. However, the almost unanimous negative impact on physical activity during the pandemic found in this review, shows again the importance of more attention and guidance for people with physical disabilities and/or chronic diseases because it is precisely this group that can benefit a great deal from regular physical activity [5,7,61].

4.2. Impact on Sedentary Behavior during the COVID-19 Pandemic

The secondary outcome of this rapid review related to the impact of sedentary behavior during the COVID-19 pandemic. Surprisingly, sedentary behavior was measured in only one of the included studies. This one study [42] reported a negative impact of the COVID-19 pandemic on sedentary behavior [60]. A similar trend has been reported in the general

population. In the same publication period, only two articles have been identified reporting on the impact of sedentary behavior in people with medical conditions [62,63]. It is worrying that sedentary behavior was studied so little during the pandemic. Work-from-home policies that were implemented in many countries were likely to increase screen time and thus may have encouraged people to adopt sedentary behavior. Sedentary behavior is known to be a health risk independent of physical activity and therefore it is advised be studied as a separate behavior. The study by Stockwell et al. reported that the majority of the studies that measured sedentary behavior in people with medical conditions used non-validated questionnaires as well [60]. This might indicate that, in comparison with physical activity, it remains difficult to adequately measure sedentary behavior, especially among special populations such as people with disabilities and/or chronic diseases. Therefore, more research on (how to measure) sedentary behavior in specific populations is needed to better understand how to protect this population group against the risks of sedentary behavior, both during and after pandemics the magnitude of COVID-19.

4.3. Impact on Well-Being during the COVID-19 Pandemic

All of the identified studies in this review reporting on well-being demonstrated a negative impact on one or more constructs related to well-being during the first wave of the COVID-19 pandemic. Our findings align with other recent reviews reporting the negative impact of a variety of well-being constructs during the COVID-19 pandemic among different populations [20–23]. Interestingly, a recent review found that regular physical activity was related to lower levels of depression and anxiety in the general population during the COVID-19 pandemic [22] but that the pandemic had increased levels of depression and anxiety. Based on literature before the COVID-19 pandemic [14,15], it can be expected that regular physical activity may also be associated with positive outcomes on a variety of well-being constructs during the pandemic. This highlights again the importance of promoting physical activity in people with physical disabilities and/or chronic diseases.

Included studies in this review reported on a variety of well-being constructs using a variety of measurement tools, which is not surprising given the multidimensional character of the well-being. While there is a lack of consensus in the literature on how to define and operationalize well-being, which might partly depend on the research field and/or focus of a study [64], we used a general definition capturing both mental and physical components of well-being. This might be a contributing factor to the variety of measurement tools that was found [6]. Additionally, before COVID-19, measuring well-being was already more difficult for people with a disability compared with their peers without a disability [24,25]. The variety of measurement instruments used in the studies we included in this review made it difficult to compare their effect sizes directly. Moreover, our results clearly illustrate a negative impact on well-being of people with a physical disability and/or chronic disease during the first wave of the COVID-19 pandemic, regardless of how well-being is operationalized. This finding shows the importance of guidance and mental support, especially in times of crisis.

4.4. Scientific and Practical Implications

We were able to identify 29 studies conducted in 21 different countries and among 11 different groups of diagnosis. Another review studying changes in physical activity and sedentary behavior from before to during the pandemic lockdown amongst healthy children, adolescents and adults was able to include 66 studies [60]. Both showed decreased physical activity levels in almost all included studies, most likely indicating additional barriers for engagement in an active lifestyle. This is particularly relevant for populations with disabilities and chronic diseases who already experience substantial barriers to physical activity engagement [8,26,27]. Our rapid review is, to the best of our knowledge, the first study that has investigated and summarized physical activity, sedentary behavior and well-being in people with physical disabilities and/or chronic diseases during the first

wave of the COVID-19 pandemic, establishing the need for an additional focus on vulnerable populations and physical activity stimulation. Digital technology and home-based alternatives have been mentioned as ways to provide potential support mechanisms to recreational athletes during a pandemic [18]. This could be promising to include in tailored programs to promote physical activity in persons with disabilities and/or chronic disease as well, though tailoring to their specific barriers will be needed. The results of this study show practical implications for medical support staff and policy makers. Policy makers might want to give special attention to this group, especially in times of crises.

4.5. Limitations

Some limitations need to be addressed. The first limitation concerns our search strategy. While our strategy included various terms to capture "physical activity" and "sedentary behavior" constructs, only a few terms were included to capture articles reporting on "well-being". As such, we may have missed relevant articles reporting on the impact of well-being during the pandemic, possibly impacting the rigor of this review. When specifically interested in well-being, we recommend using a more comprehensive search strategy including a variety of terms to capture the well-being construct. The second limitation concerns the quality of the studies. Many of the included studies were cross-sectional studies across different setting using a variety of measurement instruments that were not validated for the population concerned, indicating that findings should be interpreted with caution. On the other hand, the fact that we were able to include already 29 studies, may highlight the urgency of studying the physical activity and well-being of people with physical disabilities and/or chronic diseases during, but perhaps also after, the pandemic. Despite these limitations, the directions of the findings (i.e., negative impact on physical activity, sedentary behavior and well-being) were consistent across almost all of the included studies. Lastly, this review focused on the impacts during the first wave of the pandemic. It is possible that there are or were other behaviors affected in subsequent waves of the COVID-19 pandemic.

5. Conclusions

Despite the large variation in methods of measuring physical activity and well-being, the vast majority of the included studies reported a negative impact on physical activity and well-being in adults with physical disabilities and/or chronic diseases during the first wave of the COVID-19 pandemic. Unfortunately, the impact on sedentary behavior was barely measured. The consistent findings of the negative impact during the COVID-19 pandemic that are reported in this rapid review illustrate the need to provide (additional) support and guidance to people with a physical disability and/or chronic disease to help them become and stay physically active and well during a pandemic.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/ijerph18126342/s1, Table S1: Physical activity pre and during lockdown.

Author Contributions: D.R.d.B.: wrote review, extracted and screened data. K.I.M.H.: wrote review, screened data. F.H., T.H., L.A.K. and F.J.H.: wrote, reviewed and critically revised review. F.H. and F.J.H. supervised D.R.d.B. and K.I.M.H. during data screening. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Details of the search strategies.

Database	Search Strategy
Pubmed	((COVID-19 [tiab] OR Sars-CoV-2 [tiab] OR coronavirus [tiab] OR corona virus [tiab]) AND ("Physical activity" [tiab] OR sport [tiab] OR sports [tiab] OR exercise [tiab] OR exercising [tiab] OR "physical training" [tiab] OR "physical performance" [tiab]) OR (COVID-19 [tiab] OR Sars-CoV-2 [tiab] OR coronavirus [tiab] OR corona virus [tiab]) AND (Sedentary behavior [tiab] OR sitting activity [tiab] OR Sedentary inactivity [tiab]) OR (COVID-19 [tiab] OR Sars-CoV-2 [tiab] OR coronavirus [tiab] OR corona virus [tiab]) AND (Well-being [tiab] OR Wellness [tiab] OR Wealth [tiab] OR Welfare [tiab]))
CINAHL	((AB (COVID-19 OR Sars-CoV-2 OR coronavirus OR corona virus) OR TI (COVID-19 OR Sars-CoV-2 OR coronavirus OR corona virus)) AND ((AB (Physical activity OR Sport OR sports OR Exercise OR exercising OR Physical training OR Physical performance) OR TI (Physical activity OR Sport OR sports OR Exercise OR exercising OR Physical training OR Physical performance)) OR (AB (Sedentary behavior OR Sitting activity OR Sedentary inactivity) OR TI (Sedentary behavior OR Sitting activity OR Sedentary inactivity)) OR (AB (Well-being OR Wellness OR Wealth OR Welfare) OR TI (Well-being OR Wellness OR Wealth OR Welfare))))
PsycInfo	((AB (COVID-19 OR Sars-CoV-2 OR coronavirus OR corona virus) OR TI (COVID-19 OR Sars-CoV-2 OR coronavirus OR corona virus)) AND ((AB (Physical activity OR Sport OR sports OR Exercise OR exercising OR Physical training OR Physical performance) OR TI (Physical activity OR Sport OR sports OR Exercise OR exercising OR Physical training OR Physical performance)) OR (AB (Sedentary behavior OR Sitting activity OR Sedentary inactivity) OR TI (Sedentary behavior OR Sitting activity OR Sedentary inactivity)) OR (AB (Well-being OR Wellness OR Wealth OR Welfare) OR TI (Well-being OR Wellness OR Wealth OR Welfare))))
Embase	(('covid 19':ab,ti OR 'sars cov 2':ab,ti OR coronavirus:ab,ti OR 'corona virus':ab,ti) AND ('physical activity':ab,ti OR sport:ab,ti OR sports:ab,ti OR exercise:ab,ti OR exercising:ab,ti OR 'physical training':ab,ti OR 'physical performance':ab,ti) OR ('covid 19':ab,ti OR 'sars cov 2':ab,ti OR coronavirus:ab,ti OR 'corona virus':ab,ti) AND ('sedentary behavior':ab,ti OR 'sitting activity':ab,ti OR 'sedentary inactivity':ab,ti) OR ('covid 19':ab,ti OR 'sars cov 2':ab,ti OR coronavirus:ab,ti) AND ('well being':ab,ti OR wellness:ab,ti OR wealth:ab,ti OR welfare:ab,ti) AND english:la AND [2019–2020]/py)

Table A2. List of excluded articles during full-text screening.

Reference	Exclusion Criteria
Balducci and Coccia (2020) [65]	Study is a commentary (out of study design).
Bonora et al. (2020) [66]	Study reported different outcomes (out of outcomes).
Boyle et al. (2020) [67]	Study is a commentary (out of study design).
Chung et al. (2020) [68]	Study has a too young population (out of population).
Cuschieri and Grech (2020) [69]	Study is a literature study (out of study design).
Fernandez-del-Valle et al. (2020) [70]	Study is a commentary (out of study design).
Giebel et al. (2020) [71]	Study reported effects in dementia (out of population).
Hall and Church (2020) [72]	Study is a review (out of study design).
Hudson and Sprow (2020) [73]	Study is a commentary (out of study design).
Jakiela et al. (2020) [74]	Study is a recommendation (out of study design).
Leung et al. (2020) [75]	Study is a review (out of study design).
López-Sánchez et al. (2020) [76]	Study is published on 10 October (out of publish date).
Mobasheri (2020) [77]	Study is an editorial (out of study design).
Moghadasi (2020) [78]	Study did not make a comparison with situation before the COVID-19 pandemic (out of comparison).
Motl et al. (2020) [79]	Study is an editorial (out of study design).
Orhurhu et al. (2020) [80]	Study is an editorial (out of study design).
Palmer et al. (2020) [81]	Study is a review (out of study design).

Table A2. *Cont.*

Reference	Exclusion Criteria
Peçanha et al. (2020) [82]	Study is a review (out of study design).
Quinn et al. (2020) [83]	Study is an implementation study (out of study design).
Rhodes et al. (2020) [84]	Study is a recommendation (out of study design).
Sennott et al. (2020) [85]	Study is a commentary (out of study design).
Speretta and Leite (2020) [86]	Study is an editorial (out of study design).
Tornese et al. (2020) [87]	Study has a too young population (out of population).
Verma et al. (2020) [88]	Study has a too young population (out of population).

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The Effect of Social Isolation on Physical Activity during the COVID-19 Pandemic in France

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Abstract: The objective of this cross-sectional study is to analyze the changes in physical activity (PA) practice of a sample of 2099 French adults, mostly females, who answered an online questionnaire during the first COVID-19 lockdown (March–May 2020). A descriptive analysis of participants was performed using relative frequencies. Chi-squared tests were performed to compare the responses of selected variables. Multinomial logistic regressions were performed to compare the variations of PA with all the variables identified. The age of participants ranged from 18 to 88. Among people who practiced PAs before the first lockdown, the probability to keep practicing PAs is higher among those with a lower level of education, among housewives and retirees and among those who lived in cities of 10,000–19,999 inhabitants. For those who did not practice PAs before the social distancing, the probability of starting to practice is greater in those with a lower level of education and for those who suffered from a chronic disease. Our results place the emphasis on the complexity and multifactoriality of the changes that emerged during the first lockdown. The "education" factor emerges, as a significant determinant of PA that should certainly be explored further.

Keywords: lifestyles; social distancing; lockdown; sedentarity; education; covid-19

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1. Introduction

Since its first appearance in Wuhan (China), around mid-December 2019, the coronavirus pandemic has started to spread across the world. The steady increase in daily deaths and confirmed cases since the beginning of 2020 has prompted the governments of affected countries to adopt protection strategies, relying mainly on social distancing and other containment actions. To combat the epidemic, a so-called lockdown was put in place in France from 17 March to 11 May 2020: most workplaces and public places, including schools, shops, bars and restaurants, were closed or made accessible in a limited way. The daily lives of millions of French people have suddenly been transformed, leading to a significant change in lifestyles, family relationships and work routines, with significant consequences on their quality of life and psychological well-being, in the short, medium and long term [1].

In these extraordinary times the coronavirus crisis was been enormously covered and discussed in both the media and academia. From early on, this content also focused on the implications of the virus for sport, exercise and physical activity (PA) [2]. However, less is known about the consequences on the practice of PA and as concerns the changes in lifestyle in the short, medium and long term. In this paper, we analyze the impact of social distancing on the practice of PA of a sample of French adults who answered an online questionnaire.

Loneliness and social isolation are usually associated with poor mental and physical health and pose an important risk factor as regards the probability of experiencing the most common mental disorders (e.g., anxiety and depression) [3]. For example, sociability [4] and also non-sedentary lifestyles are usually associated with reduced overall mortality, an increase in life expectancy and a greater likelihood of living an old age in good conditions [5]. Unhealthy lifestyles and problematic behaviors are risk factors for physical [6] and mental health [7]. Strong evidence associates physical inactivity and sedentary behaviour with an increased risk of chronic diseases, which are the leading causes of death worldwide [8].

Scientific evidence leaves no doubt about the need to lead an active physical life to develop and protect one's overall health at all ages [9]. According to the WHO [10], today, physical inactivity and a sedentary lifestyle are the fourth leading cause of death worldwide and are a major public health problem. Furthermore, sedentary lifestyles lead to physiological disorders, which in turn generate significant costs in terms of health expenditure [11]. PA promotion to prevent the pandemic spread of diseases linked to physical inactivity and sedentary lifestyles, and to improve populations' health, has been for decades a core objective of health strategies and policies globally [12].

The coronavirus crisis radically changed this assumption. The mandated restrictions on PA, which widely affected those related to work, commuting, sport and exercise, disrupted the PA routine of millions of people and generated a contradictory situation. On the one hand, most kinds of PAs were perceived as risky behaviours, being a way to spread COVID-19. On the other hand, while taking precautions, PA remains an important tool to maintain the population healthy despite the lockdown [13–15]. Previous pandemic crises, as for example that caused by the severe acute respiratory syndrome (SARS), caused serious public health consequences, not only linked to the viral infection per se. Indirect impacts on communities' health haven't been assessed systematically, although early studies on the effects of quarantine and lockdown as protective measures show its negative psychological effects on the population [16]. Previous studies related to the SARS pandemic show that the community in Hong Kong responded by adopting healthier behaviours [17]. However, some authors hypothesize that this health crisis has the potential to further impact and accelerate the physical inactivity and sedentary behaviour pandemic we have been confronted with, and failing to address, for a number of years [18], and all the risks that follow from it [19,20].

Despite the scientific consensus and the deployment of incentive policies to promote PA and engage people in more active lifestyles, the phenomena of sedentary condition and inactivity are increasing, especially in high-income countries [21]. Many scholars engaged in public health's analyzes of the present pandemic situation stress that both modifiable lifestyle factors like diet and PA [22] and mental health issues [23] should not be marginalized from policy makers' considerations.

Studies from China, the center of the first wave of the epidemic, showed how nearly 60% of Chinese adults had inadequate physical activity (95% CI 56.6%–58.3%), which was more than twice the global prevalence (27.5%, 25.0–32.2%), during the early days of the novel epidemic [24]. Starting from this background, in this paper we focus on the changes in lifestyles of a sample of French adults during the first lockdown, in the months between March and May 2020, with an emphasis on PA. In particular, we test the following hypotheses: (1) the pandemic had an impact on the frequency of physical activity; (2) sociodemographic characteristics and health conditions influence the likelihood of physical activity or not during the breakdown.

2. Materials and Methods

2.1. Design

The results presented here are part of "Pandemic Emergency in Social Perspective. Evidence from a large Web-survey research", an international exploratory research that studied the social and psychological impact of the physical distancing measures imposed

by the COVID-19 pandemic in six European countries (Italy, United Kingdom, Sweden, Czech Republic, Poland and France). The online survey included a total of 31 questions that covered the following areas: (a) Demographic information (gender, age, marital status, employment status, family, number and age of children living at home, living conditions, residential area); (b) COVID-19 experience (safety and precautionary measures adopted to reduce the risk of contagion, social relationship during the quarantine, health emergency duration expectations, post-COVID scenario prevision, personal testing and outcome for COVID-19, loss of relatives or friends due to COVID-19); (c) COVID-19 and media source information (level of information perceived, information sources and channels); (d) COVID-19 risk perception (fear of getting sick, general and personal concern regarding the virus); (e) Lifestyle behaviours (diet, alcohol, and tobacco consumption during the pandemic, physical activity); (f) Perceived Stress: the 8-item version of Personal Health Questionnaire Depression Scale (PHQ-8), scored basing on Kroenke et al. [25]; (g) Health condition (chronic health conditions, general health status, daily activity abilities).

The survey was administered using the Qualtrics web survey platform. Data collection occurred between March and June 2020. The respondents were recruited through a "snowball" non-probabilistic sampling strategy, through the Facebook platform. In particular, we shared the link to our web survey in Facebook groups which were dedicated to the COVID-19 pandemic. The inclusion criterion was the age of majority. The study was approved by the Ethics Committee of the Policlinico Gemelli, Catholic University of the Sacred Heart of Rome (Prot. N. 00255223/20).

2.2. Statistical Analysis

A descriptive analysis of participants was performed using relative frequencies. Chi-squared tests were performed to compare the responses in the selected variables based on gender and PA practice during the period of social distancing. In order to calculate the odds ratio (OR) and its 95% confidence interval of the variables in which there were statistical significance based on PA practice during the period of social distancing, a multinomial logistic regression model was done using all these variables. Additionally, two other multinomial logistic regression models were done using the same variables in order to calculate the OR for the changes from "no sport practice before social distancing" to "practice during this period", and from "sport practice before social distance" to "no practice during this period" as dependent variables, both of them dichotomous variables. All data were analyzed using SPSS software and statistical significance was considered as $p < 0.05$.

3. Results

We received 2410 answers in France. After excluding people who did not answer all questions, data of a total of 2099 participants, 81.6% of which were females, were considered for the analysis. The age of participants ranged from 18 to 88 with a mean age of 41.1 $\pm$12.7. Table 1 shows the socio-demographic characteristics of participants as well as responses to health and PA's practice questions by sex. Most participants were in a relationship, cohabitant or married (65.4%), with a university degree (62%), workers (68.4%) and lived in a city with less than 100.000 inhabitants (72.4%). As for people living in the same household during the social distancing period, only 15.5 % lived alone and 37.4% lived without children all or some of the time. Regarding the health related questions, only 5.2% reported bad or very bad health, 30.6% suffered chronic diseases, 10.5% reported serious limitations in their daily activities and 27.6% scored as "moderate", "moderate severe" or "severe depression" in the Personal Health Questionnaire Depression Scale (PHQ-8) [26]. Concerning PA's practice, 54.1% reported they regularly practiced sports before confinement and 57.3% said they practiced a PA during the period of social distancing (25.9% of them started to practice PA during this period). Analyzing changes in PA practice during the period of social distancing, 34.3% of people who did not practice

any PA before this period started to, and 22.2% of those who practiced PA before this period stopped.

Table 1. Sociodemographic characteristics of participants (n = 2099, 387 males and 1712 females).

Variable	Male	Female	All	p
Age group				
18–24	15.0%	9.6%	10.6%	
25–34	22.7%	22.7%	22.7%	
35–44	22.0%	27.9%	26.8%	0.003
45–54	20.7%	24.0%	23.4%	
55–64	14.7%	12.6%	13.0%	
65+	4.9%	3.2%	3.5%	
Marital status				
Single	27.6%	20.4%	21.8%	
In a relationship and cohabitant	31.3%	35.1%	34.4%	0.001
Married	32.6%	30.7%	31.0%	
Separated, divorced or widow	8.5%	13.8%	12.8%	
Educational level				
No education or Primary school	0.3%	0.4%	0.4%	
Lower secondary school	7.8%	9.7%	9.3%	
Diploma/upper secondary school	15.8%	16.0%	15.9%	0.018
Degree	58.9%	62.7%	62.0%	
Master, PhD or post-degree	17.3%	11.2%	12.3%	
Professional status				
Worker	66.7%	68.8%	68.4%	
I am looking for a new job	7.5%	6.8%	6.9%	
Housewife	0.5%	3.9%	3.3%	0.001
Student	12.1%	9.2%	9.7%	
Retired	8.5%	5.6%	6.1%	
Other conditions	4.7%	5.7%	5.5%	
City inhabitants				
500,000 or more	16.1%	9.6%	10.8%	
250,000–499,999	5.2%	5.9%	5.8%	
100,000–249,999	12.2%	10.7%	11.0%	0.007
20,000–99,999	23.7%	25.1%	24.8%	
10,000–19,999	9.6%	11.4%	11.0%	
Less than 10,000	33.1%	37.4%	36.6%	
How many people currently live in the house where you are spending your social distancing period or most of your time?				
I live alone	19.6%	14.5%	15.5%	
2 persons	31.5%	30.7%	30.8%	0.054
3 persons	19.1%	22.3%	21.7%	
4 or more persons	29.7%	32.5%	32.0%	
How many children do you have living with you all or some of the time				
None	50.5%	34.4%	37.4%	
One	12.7%	16.6%	15.9%	0.000
Two	23.6%	32.6%	30.9%	
Three or more	13.2%	16.4%	15.8%	
Generally, how is your health?				
Very good/good	76.8%	72.5%	73.3%	0.235
Nor good or bad	18.5%	22.2%	21.5%	
Bad/very bad	4.7%	5.3%	5.2%	
Are you suffering from chronic diseases or long-lasting health problems?				0.145
Yes	27.4%	31.3%	30.6%	
No	72.6%	68.7%	69.4%	

Table 1. *Cont.*

Variable	Male	Female	All	*p*
Due to health problems, do you have any limitations in your daily activities?				
Serious limitations	9.4%	10.8%	10.5%	0.303
Not serious limitations	16.0%	18.7%	18.2%	
No limitations	74.6%	70.6%	71.3%	
Depression level (PHQ-8)				
No depression	10.9%	7.2%	7.9%	
Minimal	40.5%	29.3%	31.4%	0.000
Mild	27.7%	34.4%	33.2%	
Moderate	12.0%	17.5%	16.5%	
Moderate severe or severe	8.8%	11.6%	11.1%	
Before social distancing, did you regularly practice PA?				0.163
Yes	57.3%	53.3%	54.1%	
No	42.7%	46.7%	45.9%	
During the period of social distancing, are you practicing PA?				
No	39.1%	42.9%	42.2%	0.347
Yes, with the same frequency as before	21.8%	18.9%	19.4%	
Yes, although less frequently	25.1%	23.1%	23.4%	
Yes, I've started to do it since I've been in social distancing period	14.0%	15.2%	15.0%	

Values in percentages. *p*: *p* of Chi-squared test.

Focusing on PAs' practice during the period of social distancing, we can find the answers on Table 2 ("No practice"; "Practice with the same frequency as before"; "Practice, although less frequently"; "Started to practice in the social distancing period"). These answers are based on the socio-demographic and health-related characteristics of participants. We found statistically significant differences based on all variables except for "marital status" ($p = 0.059$) and "number of people who live together" ($p = 0.249$).

Table 3 shows the results of the multivariate regression for the PAs' practice during the social distancing period, using as reference category "not practiced AP during the social distancing period", and Table 4 shows the results of the multivariate regression for the PA's practice changes during the social distancing period. Among people who practiced PAs before the social distancing period, the probability to keep practicing PAs is higher among those with a lower level of education (1.96 times), among housewives and retirees (2.94 and 2.86 times respectively) and among those who live in cities of 10,000–19,999 inhabitants. Concerning those who did not practice PAs before the period of social distancing, the probability of starting to practice is greater in those with a lower level of education (3.12 and 2.22 for "lower secondary school or less" and "Diploma/upper secondary school" respectively) as well as for those who suffer from a chronic disease (1.51 times).

Table 2. Responses to During the period of social distancing, are you practicing PA? (n = 2099, 387 males and 1712 females).

Variable	No Practice	Practice with the Same Frequency as Before	Practice, although Less Frequently	Yes, Started to Practice in Social Distancing Period	p
Age category					
18–24	36.8%	18.2%	18.2%	26.8%	
25–34	41.4%	21.1%	19.4%	18.1%	
35–44	42.5%	16.5%	26.3%	14.7%	0.000
45–54	44.9%	21.0%	23.3%	10.8%	
55–64	43.6%	20.5%	24.5%	11.4%	
65+	37.8%	18.9%	40.5%	2.7%	
Marital status					
Single	36.7%	21.1%	24.4%	17.8%	
In a relationship and cohabitant	42.2%	20.1%	21.6%	16.1%	0.059
Married	43.4%	18.4%	25.5%	12.8%	
Separated, divorced or widow	48.3%	17.1%	21.9%	12.6%	
Educational level					
No education or Primary school	100.0%				
Lower secondary school	61.2%	15.8%	11.2%	11.7%	
Diploma/upper secondary school	49.4%	16.2%	18.3%	16.2%	0.000
Degree	38.5%	19.9%	26.0%	15.6%	
Master, PhD or post-degree	35.2%	24.2%	27.3%	13.3%	
Professional status					
Worker	41.5%	20.2%	23.8%	14.5%	
I am looking for a new job	45.5%	21.4%	17.2%	15.9%	
Housewife	56.5%	13.0%	20.3%	10.1%	0.000
Student	37.1%	16.3%	18.8%	27.7%	
Retired	43.0%	19.5%	34.4%	3.1%	
Other conditions	45.7%	15.5%	25.0%	13.8%	
In the city where you live, what is the approximate number of inhabitants?					
500.000 or more	37.3%	20.0%	24.0%	18.7%	
250.000–499.999	43.7%	19.3%	21.0%	16.0%	
100.000–249.999	35.1%	18.9%	29.8%	16.2%	0.015
20.000–99.999	40.3%	21.9%	22.7%	15.1%	
10.000–19.999	54.8%	16.5%	17.0%	11.7%	
Less than 10.000	42.6%	18.4%	24.6%	14.5%	
How many people currently live in the house where you are spending your social distancing period or most of your time?					
I live alone	39.2%	20.4%	28.4%	12.0%	
2 persons	40.9%	21.2%	23.1%	14.7%	0.249
3 persons	43.0%	18.1%	23.6%	15.4%	
4 or more persons	44.1%	18.1%	21.4%	16.4%	
How many children do you have living with you all or some of the time					
None	36.6%	21.3%	23.6%	18.6%	
One	45.8%	17.8%	22.6%	13.9%	0.005
Two	44.7%	18.0%	24.7%	12.6%	
Three or more	46.8%	19.0%	21.8%	12.4%	
Generally, how is your health?					
Very good/good	22.2%	24.5%	14.8%	22.2%	0.000
Nor good or bad	11.5%	20.8%	15.6%	11.5%	
Bad/very bad	14.0%	20.6%	15.0%	14.0%	

Table 2. *Cont.*

Variable	No Practice	Practice with the Same Frequency as Before	Practice, although Less Frequently	Yes, Started to Practice in Social Distancing Period	*p*
Are you suffering from chronic diseases or long-lasting health problems?					0.001
Yes	48.3%	17.6%	22.5%	11.6%	
No	39.3%	20.3%	24.0%	16.5%	
Due to health problems, do you have any limitations in your daily activities?					
Serious limitations	50.0%	11.8%	24.1%	14.2%	0.006
Not serious limitations	46.3%	15.8%	24.5%	13.4%	
No limitations	40.2%	21.2%	23.1%	15.5%	
Depression level					
No depression	35.8%	28.4%	24.7%	11.1%	
Minimal	37.7%	24.1%	25.2%	13.0%	
Mild	43.3%	18.5%	21.7%	16.6%	0.000
Moderate	44.7%	14.2%	22.8%	18.3%	
Moderate severe or severe	49.8%	11.0%	25.6%	13.7%	
Before social distancing, did you regularly practice sports?					0.000
Yes	22.2%	33.9%	41.0%	2.9%	
No	65.7%	2.3%	2.8%	29.2%	

Values in percentages. *p*: *p* of Chi-squared test.

Table 3. Results of the multivariate regression for the PA practice during the period of social distancing (*n* = 2099, 387 males and 1712 females).

Variable	Practice with the Same Frequency as Before **		Practice, Although Less Frequently **		Yes, Started to Practice in Social Distancing Period **	
	OR	95% CI	**OR**	**95% CI**	**OR**	**95% CI**
Age category						
18–24	1.04	0.33–3.25	0.33 *	0.12–0.89	1.76	0.29–10.55
25–34	0.96	0.35–2.66	0.32 *	0.14–0.75	1.36	0.24–7.68
35–44	0.72	0.26–1.99	0.46 *	0.2–1.06	1.13	0.2–6.38
45–54	0.86	0.31–2.36	0.37 *	0.16–0.86	0.82	0.14–4.68
55–64	1.00	0.39–2.55	0.49	0.23–1.06	1.19	0.22–6.57
65+	1.00	-	1.00	-	1.00	-
Educational level						
Lower secondary school or less	0.35*	0.2–0.62	0.22	0.12–0.39	0.59	0.31–1.12
Diploma/upper secondary school	0.54*	0.34–0.88	0.47	0.3–0.75	0.80	0.47–1.37
Degree	0.80	0.55–1.17	0.95	0.66–1.37	1.07	0.69–1.68
Master, PhD or post-graduate degree	1.00	-	1.00	-	1.00	-
Professional status						
Worker	0.91	0.5–1.65	0.72	0.43–1.22	1.03	0.54–1.94
I am looking for a new job	0.88	0.42–1.84	0.49 *	0.25–0.98	0.96	0.44–2.08
Housewife	0.50	0.18–1.33	0.59	0.26–1.34	0.68	0.24–1.88
Student	0.83	0.37–1.86	0.70	0.33–1.47	1.38	0.62–3.06
Retired	0.71	0.28–1.79	0.72	0.33–1.61	0.20*	0.05–0.92
Other conditions	1.00	-	1.00	-	1.00	-

Table 3. *Cont.*

Variable	Practice with the Same Frequency as Before **		Practice, Although Less Frequently **		Yes, Started to Practice in Social Distancing Period **	
	OR	95% CI	**OR**	**95% CI**	**OR**	**95% CI**
In the city where you live, what is the approximate number of inhabitants?						
500.000 or more	1.08	0.7–1.67	1.04	0.69–1.56	1.25	0.79–1.96
250.000–499.999	1.00	0.57–1.75	0.76	0.44–1.32	0.93	0.51–1.7
100.000–249.999	1.23	0.79–1.92	1.51 *	1.02–2.24	1.31	0.83–2.09
20.000–99.999	1.16	0.84–1.6	0.86	0.63–1.17	0.95	0.66–1.36
10.000–19.999	0.62 *	0.39–0.98	0.51 *	0.34–0.78	0.59 *	0.36–0.97
Less than 10.000	0.00	-	0.00	-	0.00	-
Generally, how is your health?						
Very good/good	1.20	0.61–2.35	1.81	1–3.29	0.88	0.45–1.71
Nor good or bad	0.58	0.29–1.16	1.20	0.66–2.19	0.85	0.43–1.65
Bad/very bad	1.00	-	1.00	-	1.00	-
Are you suffering from chronic diseases or long-lasting health problems?						
Yes	1.16	0.84–1.61	0.84	0.62–1.14	0.72	0.5–1.04
No	0.00	-	0.00	-	0.00	-
Due to health problems, do you have any limitations in your daily activities?						
Serious limitations	0.60	0.35–1.01	1.21	0.79–1.85	1.03	0.63–1.68
Not serious limitations	0.78	0.54–1.14	1.16	0.83–1.62	0.97	0.65–1.46
No limitations	1.00	-	1.00	-	1.00	-
Depression level						
No depression	2.69 *	1.44–5.04	0.91	0.52–1.6	1.35	0.66–2.73
Minimal	2.00 *	1.2–3.35	0.86	0.57–1.31	1.23	0.74–2.06
Mild	1.51	0.9–2.51	0.75	0.5–1.12	1.39	0.86–2.26
Moderate	1.22	0.69–2.14	0.85	0.54–1.32	1.42	0.85–2.39
Moderate severe or severe	1.00	-	1.00	-	1.00	-

*: $p < 0.05$; ** Note: Reference category: No practice sports during the period of social distancing.

Table 4. Results of the multivariate regression for the PA practice changes during the period of social distancing (n = 2099, 387 males and 1712 females).

Variable	FROM YES TO NO **		FROM NO TO YES ***	
	OR	**95% CI**	**OR**	**95% CI**
Age category				
18–24	0.34	0.1–1.21	1.71	0.38–7.65
25–34	0.56	0.19–1.65	0.96	0.23–3.95
35–44	0.58	0.2–1.71	0.88	0.21–3.63
45–54	0.43	0.15–1.27	0.70	0.17–2.89
55–64	0.50	0.2–1.29	0.92	0.23–3.63
65+	1	-	1	-
Educational level				
Lower secondary school or less	0.51 *	0.26–1	0.32 *	0.16–0.62
Diploma/upper secondary school	1.01	0.56–1.84	0.45 *	0.26–0.79
Degree	1.07	0.67–1.71	0.78	0.49–1.25
Master, PhD or post-degree	1	-	1.00	-
Professional status				
Worker	0.72	0.34–1.53	0.86	0.46–1.59
I am looking for a new job	1.23	0.43–3.53	0.81	0.38–1.72
Housewife	0.34 *	0.12–0.97	0.83	0.31–2.23
Student	0.92	0.33–2.57	1.00	0.45–2.22
Retired	0.35 *	0.13–0.96	0.45	0.12–1.65
Other conditions	1	-	1	-

Table 4. *Cont.*

Variable	FROM YES TO NO **		FROM NO TO YES ***	
	OR	95% CI	OR	95% CI
In the city where you live, what is the approximate number of inhabitants?				
500.000 or more	0.97	0.58–1.62	1.16	0.71–1.9
250.000–499.999	0.98	0.49–1.95	0.74	0.38–1.42
100.000–249.999	1.31	0.77–2.22	1.33	0.81–2.18
20.000–99.999	1.04	0.7–1.55	0.93	0.63–1.35
10.000–19.999	0.49 *	0.3–0.8	0.63	0.38–1.03
Less than 10.000	1	-	1	-
Generally, how is your health?				
Very good/good	1.15	0.52–2.55	0.86	0.44–1.68
Nor good or bad	0.73	0.33–1.6	0.83	0.42–1.64
Bad/very bad	1	-	1	-
Are you suffering from chronic diseases or long-lasting health problems?				
Yes	1.09	0.74–1.6	0.66 *	0.45–0.97
No	1	-	1	-
Due to health problems, do you have any limitations in your daily activities?				
Serious limitations	0.88	0.49–1.58	1.27	0.78–2.06
Not serious limitations	0.98	0.64–1.51	1.02	0.67–1.56
No limitations	1	-	1	-
Depression level				
No depression	1.54	0.75–3.16	1.41	0.67–2.99
Minimal	1.54	0.89–2.66	1.32	0.77–2.25
Mild	0.96	0.57–1.6	1.44	0.86–2.43
Moderate	0.92	0.52–1.63	1.44	0.82–2.51
Moderate severe or severe	1	-	1	-

*: $p < 0.05$; ** Reference category: Stopped doing sport during confinement.; *** Reference category: Continued without sports practice during confinement.

4. Discussion

As with many other recent research that analyzed lifestyle changes during the social distancing period, our findings are complex and somewhat ambiguous (i.e., as for alcohol consumption [27]). Some of our results were partially unexpected.

First, some aspects that we thought might have an effect on PA don't seem so significant. This is the case of the age category, which does not seem to have a significant effect on its variation during the first lockdown. Consistently with other research relating to the effect of age on the quantity and quality of physical activity [28], we would have expected a less ambiguous correlation during the social distancing period too and a more important "age effect".

Another unexpected result was related to those who did not practice PAs before the first lockdown: those who suffered from a chronic disease had 1.51 times more probability of starting to practice. This is a population at risk of a sedentary lifestyle which, overall, is not always easy to involve in PA. In particular, a recent study on lifestyle adherence in stay-at-home patients with chronic coronary syndromes found that almost half (45%) of participants reported a reduction in physical activity during first French lockdown [29].

Other aspects that we took for granted have been confirmed by data analysis: for example, concerning the psychological aspects that we have considered using the PHQ-8 questionnaire, as other studies point out too [30] the fact of being in an healthy or "normal" mental health condition (we refer to the PHQ questionnaire's categories "no depression" or "minimal depression"), allows to give continuity over time to the practice of physical activity, and we can also assume that it helps to maintain a healthy lifestyle. Conversely,

many cross-sectional studies have reported that depressed patients are more sedentary [31]. However, this association may be bidirectional: problematic mental health may lead to decreased levels of exercise due to low motivation and energy and decreased exercise may be a risk factor for depression [30].

If we focus on healthier conducts, our data show that having a lower educational level and living in a small town (or—we suppose basing on the classification proposed by Jousseaume and Talandier in 2016 [32] concerning the French context—in a rural area town, but our questionnaire doesn't allow us to confirm this aspect, unfortunately) are positive factors of influence (determinants) with respect to the fact of continuing practicing PAs during the first lockdown, or starting practicing a PA if they never did. An hypothesis to explain why people who leave in a small town practice more PA could be that they went out even if there was a ban on going out (in a rural area there is less control): our analysis show a strong correlation between the fact of living in one of these towns and the tendency to practice PA, and thus confirms this hypothesis. Our data does not allow us to point out the difference between those who have enough space to practice in their living environment and those who do not. We can assume that the lockdown experience changed something in the perception and future design of living spaces. A survey carried out on a sample of 1056 people by Opinion Way for Artémis Courtage in June 2020 highlights the new appeal of housing with outdoor space: 10% of participants declared they wanted to move in a rural area; 29% of twenty-five-to-thirty-fours wanted a garden and 23% a terrace [33].

As for the educational level and the place of residence, we note that there is also a strong correlation with regard to whether or not to practice sport before the first lockdown (Table 2): again, there is a more important number of people "not practicing sport" among those with a "lower secondary school" or a "diploma/upper secondary school" educational level, living in small towns. Furthermore, those having a "lower secondary school" educational level are the ones having a positive balance between those who practiced less and those who started. But looking more deeply, those who have a low level of education are also those who have shown a greater variability in the practice of physical activity between before and during the first lockdown (Table 4).

Finally, a last interesting aspect related to healthy practices: we note an interesting continuity in the practice of PA among retirees who practiced even before the first lockdown. This is certainly an interesting indicator of a healthy lifestyle that tries to remain so even in situations of crisis. Furthermore, recent studies have clearly demonstrated the mental health benefits of physical activity in adults [34] and older adults [35] during lockdown. In particular, in a recently published study, Faulkner et al. [34] show that participants who reported a negative change in exercise behaviour during the initial COVID-19 restrictions demonstrated poorer mental health and well-being compared to those demonstrating either a positive-or no change in their exercise behaviour.

Our data, in fact, show overall a positive increase in the amount of PA practice in our sample, which is an indicator of improvement lifestyles during the first lockdown. This result is in contrast to a Spanish research in which a decrease in PA was found [36].

5. Conclusions

Certainly, our results place the emphasis, once again and in accordance with what emerged in the literature, on the complexity and multifactoriality of the changes that emerged during the first lockdown, in relation to the various profiles of respondents. In this complexity, the "education" factor emerges, as a significant determinant of PA that certainly has to be explored further. In order to understand these results, it will be necessary to integrate other variables, such as the motivation, and to explore the subjective dimension of the experience of social distancing, in relation to the practice of PAs.

From the data in our possession there does not seem to be a main influencing factor (determinant) of PA during the first lockdown. This leads us to open new avenues for reflection: from a perspective of prevention, accompaniment of change and/or intervention, it is important to identify the main factors of influence (or determinants) of PA. These are

some factors that we have chosen not to analyze, given the descriptive and exploratory nature of our work, but which emerge between the lines of our results, when, analyzing the impact of the lockdown, we can observe the differences between some categories and the role of the educational level emerges ambiguously.

The analysis of these factors could bring out the social inequalities at the basis of the changes that we have observed and could therefore provide the tools to be able to build adapted health and PA policies if some new lockdowns occur.

6. Limits of the Study

The respondents were recruited through a "snowball" non-probabilistic sampling strategy, through the Facebook platform. This means that the people who responded to our questionnaire were also the most active on social media, especially on Facebook. Although non-probabilistic sampling strategies do not allow to obtain representative samples of the entire population, in accordance with Brickman Bhutta [37], the administration of an online survey through the use of social networks offers new opportunities for scholars to collect data faster, at lower cost and with less need for assistance for responding compared to what could be possible through traditional data collection methods: for these reasons, "*Facebook may be a useful tool for exploratory work and for rapid pretesting of surveys destined for dissemination* via *traditional method*" ([37], p. 59). Additionally, the cross-sectional design limits the ability to draw on causal associations.

7. Key Points

- Among those who practiced PA before the social distancing period, the probability of keeping practicing PA was higher among those with a lower level of education, housewives, retirees, and those who lived in small cities.
- As for those who did not practice PA before the social distancing, the probability of starting to practice is greater in those with a lower level of education and for those who suffered from a chronic disease.
- Our results place the emphasis on the complexity of the changes that emerged during the first lockdown.
- In this complexity, the "education" factor emerges as a significant determinant of PA that certainly should be explored further.

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A Cross-Country Examination on the Fear of COVID-19 and the Sense of Loneliness during the First Wave of COVID-19 Outbreak

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Abstract: The aim of the current study is to examine gender, age. and cross-country differences in fear of COVID-19 and sense of loneliness during the lockdown, by comparing people from those countries with a high rate of infections and deaths (e.g., Spain and Italy) and from countries with a mild spread of infection (e.g., Croatia, Serbia, Slovakia, Slovenia, and Bosnia and Herzegovina). A total of 3876 participants (63% female) completed an online survey on "Everyday life practices in COVID-19 time" in April 2020, including measures of fear of COVID-19 and loneliness. Males and females of all age groups in countries suffering from the powerful impact of the COVID-19 pandemic reported greater fear of COVID-19 and sense of loneliness. In less endangered countries, females and the elderly reported more symptoms than males and the young; in Spanish and Italian samples, the pattern of differences is considerably more complex. Future research should thoroughly examine different age and gender groups. The analysis of emotional well-being in groups at risk of mental health issues may help to lessen the long term social and economic costs due to the COVID-19 outbreak.

Keywords: COVID-19; fear of COVID-19; loneliness; cross-country; psychosocial distress

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1. Introduction

By the mid of January 2020, the Chinese government had quarantined the city of Wuhan (11 million inhabitants) and subsequently extended the measure to Hubei province (60 million inhabitants) to contain the Coronavirus Infectious Disease 2019 (COVID-19) epidemic. Since that time, there has been a progressive spread of the virus throughout the world, with 24,854,140 reported infections and 838,924 deaths attributed to COVID-19 by 30 August 2020 [1]. On 11 March 2020, the World Health Organization (WHO) declared a state of pandemic. Quarantine (i.e., the segregation of one or more healthy people inside their own homes, to prevent infection and the virus spreading) was considered one of the most helpful measures in containing the infection. Most countries issued varying degrees of "shelter-in-place" orders [2] and almost one-third of the global population has faced some form of quarantine [1] due to the COVID-19 outbreak in the last few months. However, there is evidence that undergoing quarantine can have detrimental effects on people's psychological health [3], with anxiety, anger, insomnia, and somatic symptoms, mainly due to the loss of freedom, the separation from loved ones, uncertainty over the disease, and shortage of everyday supplies.

To date, there is some evidence showing the negative impact of the COVID-19 pandemic on psychological well-being [4–6]. One of the first surveys, which was conducted in China during the lockdown, showed that more than 50% of participants rated the psychological impact of COVID-19-related restrictions as moderate or severe [7], with greater difficulties associated with the effects of COVID-19 pandemic on daily life and social and work activities [8–10]. Of course, this negative impact is even greater for healthcare professionals tackling this global crisis [11], with a considerable proportion of workers reporting symptoms of depression, anxiety, and stress [12]. The negative psychological effects of the COVID-19 pandemic on the individual's mental health states were further confirmed in studies from several Western countries [13–15].

As COVID-19 continues to spread, so does the research on people's experience of fear during the pandemic. Fear of personal infection or infecting loved ones is common among people exposed to any infectious disease outbreak [3,10], and it is worth carrying out a specific examination of the characteristics of the fear of COVID-19. Globally, more than 72 million people have contracted the virus infection, and 1.6 million have died (by first week of December 2020). Thus, it is likely that the high mortality rates due to COVID-19 have negatively impacted on the individual's feelings of fear of contagion and anxiety throughout all countries of the world. In the current study, we will focus on a cross-country examination of the COVID-19 outbreak and on the fear of COVID-19, by differentiating between European countries that reported a powerful impact of the infection (e.g., Italy and Spain) and those that reported a mild impact (e.g., Croatia, Serbia, Slovakia, Slovenia, and Bosnia and Herzegovina) during the first wave of the pandemic (see Supplemental Figure S1). More specifically, during the time lag of the current study (15–28 April 2020), there has been a reported cumulative 199,414 infected and 26.977 deaths in Italy (329 infected rate /9.8 death rate), and 213,095 infected and 23.822 deaths (455/11.9) (Infected rate (infected/100.000 inhabitants, death rate (deaths/100.000)) in Spain. In only the time of the online survey, they both witnessed over 10.000 deaths. These numbers are higher than those that were officially reported in Croatia (49.7/0.7) Slovenia (67.7/1.3), Serbia (94.7/0.8), Slovakia (15.8/0.2), and Bosnia and Herzegovina (47.7/0.6). Both Italy and Spain have applied emergency epidemiological measures: first quarantine, and then total lockdown. The other countries covered by this research adopted mild restrictions, i.e., the introduction of a state of emergency, with curfew (Serbia, Bosnia and Herzegovina), the introduction of a state of emergency without curfew (Slovenia, Slovakia), and the "closure of public life" (Croatia). Given the aforementioned differences, not only in numbers of citizens infected/deceased, but also in the nature/type of epidemiological emergency measures, the investigation of differences regarding the negative consequences of the COVID-19 pandemic seems worthwhile.

Although fear is an adaptive response in the presence of danger, it has been suggested that the construct of fear of COVID-19 should be examined within an integrated complex model [16]. For example, fear of infection can trigger healthy behaviors or, on the contrary, prompt anxiety about health. Concerns and fears about one's own health and the well-being of one's own beloved ones (particularly the elderly or people suffering from any physical illness) can exacerbate feelings of anxiety. If these concerns are prolonged over time, they may increase the risk of serious mental health conditions, including anxiety disorders, stress, and trauma-related disorders [17]. Moreover, feelings of uncertainty about the future and the lack of an effective vaccine may have led people to heighten their fear of COVID-19 during quarantine. To date, some new tools for the assessment of the Fear of COVID-19 have been developed [18–20] to provide healthcare professionals with a valid measure for monitoring fear and anxiety of individuals during the COVID-19 crisis [18,21]. Previous research showed a significant association between the fear of COVID-19 and the most widely-recommended strategies to control the spread of COVID-19, such as spatial distancing and handwashing [22,23]. People with an excessive fear of the infectious outbreak are more likely to report greater psychosocial distress, whereas people showing little anxiety are more likely to disregard the physical distancing [20,24].

An important step towards understanding the critical characteristics of this construct is to examine the cross-country similarities and differences in fear of COVID-19. Although there is some evidence to suggest that fear of COVID-19 may be concentrated in those regions with the highest reported COVID-19 cases [25], there has been limited research as to whether fear may differ in those European populations subjected to a high or limited impact of the infection and to policies of strict restriction. Moreover, the association between fear of COVID-19 and social isolation during the lockdown needs to be further investigated in cross-cultural research. To date, the link between people's experience of fear of COVID-19 and feelings of loneliness has received little research attention. Although physical distancing measures have been critical in containing the rate of infection, there is concern that limits on social activities and restrictions on in-person social contacts may increase feelings of loneliness [26,27]. Prior research on the experience of loneliness in response to the social restrictions due to the COVID-19-related quarantine reported mixed findings. For example, it was shown that being under a stay-at-home order was associated with greater loneliness and health anxiety. However, the higher perceived impact of COVID-19 on participants' daily life was significantly associated with higher perceived social support and lower loneliness [14]. Moreover, a recent longitudinal study [27] showed that although people perceived an increased absence of social connections during the initial stages of the COVID-19 outbreak, they did not feel more isolated in response to the implementation of social distancing measures.

To the best of our knowledge, no previous research has examined the link between fear of COVID-19 and feelings of loneliness during the lockdown transversely across countries. It is likely that lockdown measures have resulted in worsening individual's sense of loneliness and fear of COVID-19. Although some studies showed that individuals who felt lonely in the pandemic reported symptoms of anxiety and depression [13,28], and that greater emotion regulation difficulties and depression may be risk factors for loneliness [29], interplay remains unknown between feelings of loneliness and fear of COVID-19 in countries facing varying levels of the spread of infection as well as different home-confinement policies.

The present study examines individuals' experience of fear of COVID-19 and loneliness in response to physical distancing and restriction measures undertaken to contain the outbreak of COVID-19 in different countries. More specifically, this study aims to examine potential cross-country differences in the measures of fear of COVID-19 and loneliness across two groups of European countries subject to varying impact of the COVID-19 pandemic (e.g., with regard to the number of deaths and measures of total lockdown). We hypothesize that fear of COVID would be associated with loneliness during the pandemic and can represent top stressors. Moreover, in line with prior studies [13,28], we expected that countries reporting a high death and infection rate would display a higher fear of COVID-19, associated with feelings of loneliness, compared to countries reporting a low infection and death rate in the midst of the pandemic. We also aim to examine gender and age group differences across countries. We do expect gender differences in fear of COVID-19 and loneliness, and it was hypothesized that females would report more fear of COVID-19 and would feel lonelier than males, in accordance with previous research [27,29]. Finally, we expected that the elderly would feel lonelier and would also display greater fear of COVID-19 than the young in all countries [6,13].

2. Materials and Methods

2.1. Participants and Data Collection

The sample consisted of 3876 participants (1422 males, 2442 females) from 7 European countries (Italy, Spain, Bosnia and Herzegovina, Croatia, Serbia, Slovakia, Slovenia), whose ages ranged between 18 and 82 years (M = 31.94; SD = 12.02). The majority of participants described themselves as female (N = 2442, M_{age} = 31.88 years; SD = 12.96), 1422 described themselves as male (M_{age} = 32.05 years; SD = 13.14), and 12 described themselves as other

gender (e.g., transgender, bigender, non-binary). However, given the very low number in this grouping (0.3%), in the current study, we limited data analyses to men and women.

Recruitment of participants was designed as an online survey with a general invitation to participate. Participants could "respond," i.e., choose to participate, without receiving incentives. From the point of view of sampling within the consortium of the 7 countries that conducted the study, the first target group was students of faculties of the consortium and then their wider social networks. Participants were invited to participate in the survey with personal transmission of the questionnaire via individual e-addresses databases and posting the link to the questionnaire on social networks, official webpages of partners' organizations, and local on-line newspapers.

Participants completed a 22-item online survey "Everyday life practice in COVID-19 time" during the restriction time for COVID-19 pandemic (see Supplemental information), from 15 April 2020 to 28 April 2020 [30]. Participants had to be 18 years or older and living in the European countries indicated. They were categorized into four age groups: emerging adults (between 18 and 25 years old), young adults (between 26 and 39 years old), middle-aged adults (between 40 and 60 years old), and older adults (60 years or older) (see Table 1). However, due to the COVID-19-related restrictions and the limited recruitment window (14 days) we were able to conduct a non-probability sample. All materials and procedures were reviewed and approved by the consortium of six partners from Science and Research Centre Koper, Slovenia; Faculties of Sport at University of Novi Sad, Serbia; University of Palermo, Italy; University of Zagreb, Croatia; University of Presov, Slovakia; and University of Cadiz, Spain. The study was conducted in accordance with the ethical standards of the Declaration of Helsinki, and all participants signed statements of informed consent to participate in this study. The Ethics Committee of the University of Novi Sad (Nr. 46-06-02/2020-1) approved this study prior to data collection. Each institution of the participating countries agreed to move forward with the study under the Institutional Review Board approval of the University of Novi Sad. Participants were informed that all data would have been processed and managed by the legislation for the protection of personal data and the General Data Protection Regulation (GDPR). They were able to leave the questionnaire at any stage before the submission process. Only surveys with completed mandatory questions were taken for further analysis.

Table 1. Discriminant Analysis results.

Roots Removed	Eigenvalue	Canonical Correlation	Wilks' Lambda	Chi-Squared	df	*p*
0	0.16	0.37	0.82	776.60	60	<0.001 ***
1	0.04	0.18	0.95	203.01	42	<0.001 ***
2	0.01	0.11	0.98	69.44	26	<0.001 ***
3	0.01	0.08	0.99	24.94	12	0.02 *

(*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$).

2.2. Measures

The survey was made up of socio-demographic questions (revealing age, gender, education, and nationality), the Fear of COVID-19 Scale [18], and the Three-Item Loneliness Scale [31]. The questionnaires were translated and back-translated to ensure that the wording was appropriate for Spain, Bosnia and Herzegovina, Croatia, Serbia, Slovakia, and Slovenia. The study was conducted in line with some recommendations by Swami and Barron [32] to ensure semantic equivalence. In the first step (forward translation) the original questionnaire was translated into the target languages by two mother tongue translators. Each translator produced an independent translation, and all participated to a synthesis meeting. For back translation, two separate native English-speaking translators independently translated the synthesized version of the target questionnaire into English. The forward and back translations were reviewed by a research committee with language

professionals and methodologists, in order to make final semantic adjustments and produce the final version of the measure.

2.3. Fear of COVID-19 Scale

Participants completed the Fear of COVID-19 Scale by Ahorsu et al. [18], which consists of 7 items with answers on a 5-point scale, from completely disagree to agree. It was constructed considering existing scales on fears, expert evaluations, and interviews, and it shows very good psychometric properties. Specifically, it shows stable psychometric properties across countries, with a good reliability (Cronbach alphas: Italy, 0.86; Spain, 0.87; Bosnia and Herzegovina, 0.89; Croatia, 0.85; Serbia, 0.85; Slovakia, 0.83; Slovenia, 0.85).

2.4. Three-Item Loneliness Scale

Loneliness was measured by the 3-item Loneliness Scale by Hughes et al. [31]. It consists of three items determining lack of companionship, the feeling of being left out, and the feeling of being isolated from others, measured on the frequency Hardly Ever, Some of the Time, and Often. For the purposes of the present study, the items were treated as three different indicators of feelings of loneliness.

2.5. Data Analysis

Descriptive statistics of the total result for the Fear of Covid-19 Scale and items from the Three-Item Loneliness Scale were calculated on the total sample and subgroups regarding gender, age, and country. Correlational analysis through Pearson's r was performed to see whether loneliness items and fear of COVID-19 were interrelated. Countries were divided into two groups, with, specifically, the most endangered, Italy and Spain (C2), in one group and Slovenia, Croatia, Serbia, Slovakia, and Bosnia and Herzegovina in the other group (C1).

Establishing significant multivariate differences of two or more groups was tackled by discriminant analysis [33,34]. Subsequently, the canonical multi-group discriminant analysis of groups defined by age, gender, and country was carried out on the total result of the Fear of COVID-19 Scale and items from the Three-Item Loneliness Scale, by using the Discriminant Function Analysis procedure described by Jennrich [35] in STATISTICA (version 13.0, TIBCO, Palo Alto, CA, USA). The results of multivariate and multiple-group discriminant analysis are (1) the number of significant discriminant functions, (2) the identification of variables defining each discriminant function, and (3) the mapping of the groups in the space defined by discriminant functions [36]. The significance of the first and subsequent discriminant functions was tested by Wilks' lambda values at the level of statistical significance $p < 0.01$. Standardized discriminant coefficients and correlations of independent and discriminant variables were determined. The means for the discriminant functions by group (namely, group centroids) were computed; centroids were represented in three-dimensional Cartesian space.

3. Results

3.1. Preliminary Results

Descriptive statistics are summarized in Supplement Tables S1 and S2. Twelve participants who identified as being in the "other" gender category were excluded. Therefore, the total sample size was $N = 3864$ for further testing on the Fear of COVID-19 and the Loneliness scales. Fear of COVID-19 and loneliness items (lack of companionship, feeling left out, and feeling isolated) were significantly correlated at $p < 0.01$. Independent variables distributions are significantly different from the norm because of skewness, but this should not invalidate the discriminant analysis [37,38].

3.2. Discriminant Analysis

Canonical discriminant analysis of groups defined by age, gender, and country for the Fear of COVID-19 and the Three-Item Loneliness Scale resulted in three significant

discriminant functions (see Table 1), whose discriminant coefficients are represented in Table 2. The first discriminant function is predominantly defined by the result of Fear of COVID-19 (standardized discriminant coefficient = 0.963; correlation with discriminant function = −0.896); feeling that the lack of companionship contributes to a lesser extent (standardized discriminant coefficient = −0.351; correlation with discriminant function = −0.325). The second discriminant function is mainly defined by feeling isolated from others (standardized discriminant coefficient = −0.709; correlation with discriminant function = −0.926) and the tendency to feel the lack of companionship more (standardized discriminant coefficient = −0.313; correlation with discriminant function = −0.689). The third discriminant function is determined by feeling left out (standardized discriminant coefficient = 1.233; correlation with discriminant function = 0.74); partial contributions of two further measures of loneliness are also detected, but to a much lesser extent (standardized discriminant coefficients of feeling the lack of companionship and feeling isolated are −0.489 and −0.430, respectively).

Table 2. Standardized discriminant coefficients and correlations with discriminant functions.

Items	Root 1		Root 2		Root 3	
	S	F	S	F	S	F
The Fear of COVID-19 Scale	0.963	0.896	−0.239	−0.405	−0.174	−0.048
How often do you feel that you lack companionship?	−0.351	−0.325	−0.313	−0.689	−0.489	−0.214
How often do you feel left out?	−0.028	−0.056	−0.049	−0.653	1.233	0.740
How often do you feel isolated from others?	−0.141	−0.155	−0.709	−0.926	−0.430	0.060

Note: S—Standardized discriminant coefficient; F—correlation with discriminant function.

Regarding the negative side of the first discriminant function (See Figure 1), described mainly by the lower level of Fear of COVID-19, three centroids of groups lie in less endangered countries (C1); the results of males from C1 countries are either negative or near-zero, values rising from the youngest group upwards (Table 3, Figure 1).

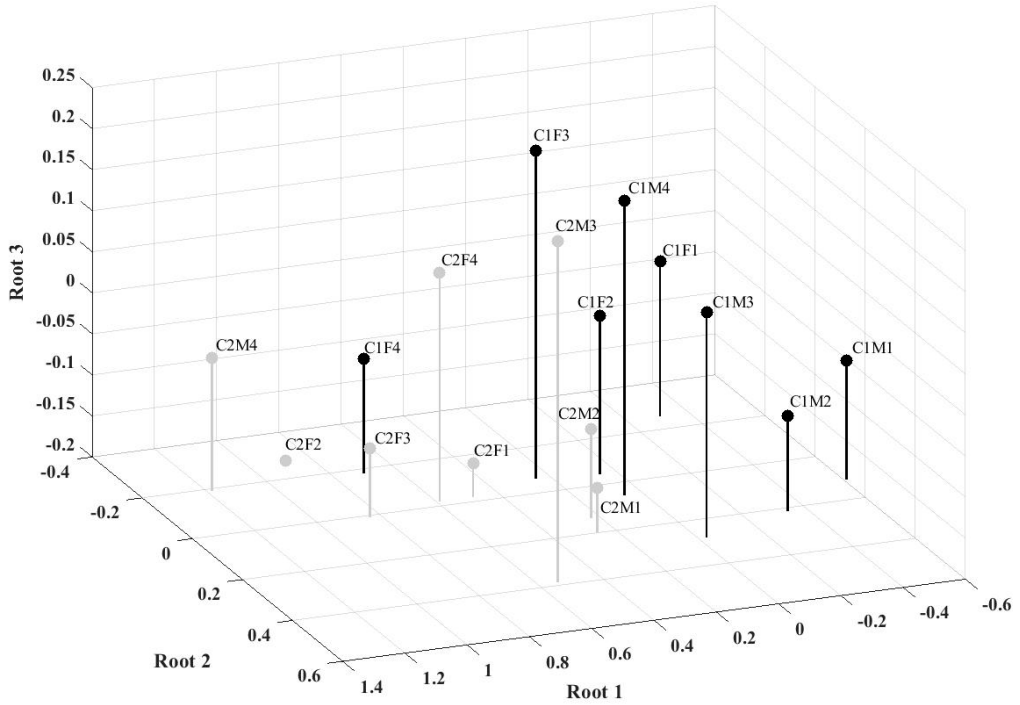

Figure 1. Centroids representation on first, second, and third discriminant functions. Note: Country: C1 and C2. Gender: M, F. Age groups: 1—emerging adults 18–25 years, 2—young adults 26–39 years, 3—middle-aged adults 40–59 years, and 4—elderly of 60 years and more.

Table 3. Centroids distinguished according to country (C1 and C2), gender (M, F), and age (1—emerging adults 18–25 years, 2—young adults 26–39 years, 3—middle-aged adults 40–59 years and 4—elderly of 60 years and more).

	Countries 1 (C1)			Countries 2 (C2)		
	Root 1	**Root 2**	**Root 3**	**Root 1**	**Root 2**	**Root 3**
M1	−0.587	0.141	−0.047	0.281	0.226	−0.138
M2	−0.316	0.244	−0.075	0.252	0.164	−0.083
M3	−0.003	0.309	0.082	0.558	0.413	0.223
M4	0.082	0.087	0.167	1.206	−0.164	−0.030
F1	−0.286	−0.229	−0.004	0.504	0.007	−0.151
F2	0.078	−0.017	0.001	0.902	−0.248	−0.192
F3	0.269	−0.036	0.207	0.859	0.036	−0.108
F4	0.727	−0.153	−0.053	0.613	0.009	0.087

The centroids of female groups from C1 countries also show that fear increases with age; compared with males, female centroids are shifted to higher values and only the youngest group centroid is positioned on the negative side of the function. All the centroids of groups from Italy and Spain (C2), on the first discriminant function, are on the positive side of the function; they do not show the same regularity as groups from less endangered countries. The first three age groups of males have lower values then corresponding female groups, but the eldest males have the highest centroid value on the first function. The emerging-adult female group has the lowest value, whereas the highest value is in the young adult female group.

The centroids of groups from less endangered countries (C1), on the second discriminant function, show that females feel isolated from others more often and feel the lack of companionship more than males. Three female groups from Italy and Spain (C2) have near-zero values and only the young adult female group has centroid on the negative side of function; males from the first three age groups have centroids on the positive side of the function, and the eldest male group has the centroid on the negative side of the function.

The third discriminant function is defined by the feeling of being left out. In the groups from less endangered countries (C1) only elderly males and middle-aged females have centroids on the positive side of the function, the others have near-zero values. Seven groups from Italy and Spain (C2) have near-zero or centroids on the negative side of the function; only the group of middle-aged males felt they were being left out more often.

4. Discussion

The present study examined cross-country differences concerning the fear of COVID-19 and loneliness due to the varying degrees of outbreak severity. Our results suggest that both males and females in European countries, in April 2020, suffering from a powerful impact of the COVID-19 pandemic (i.e., Italy and Spain) reported higher fear of COVID-19 and sense of loneliness than those in countries with a lesser spread of the virus. Consistent to our hypotheses, it is likely that the higher number of infections and deaths in the first months of the first wave of the pandemic and the strict shelter-in-place orders in Italy and Spain could have fostered heightened levels of fear of COVID-19 and feelings of loneliness. Moreover, from the analyses, it resulted that people who had a high level of fear of COVID-19 tended to suffer loneliness to a lesser extent and those feeling more isolated also tended to feel the lack of companionship. However, discriminant analysis showed that this pattern of results should be examined in more detail by considering the different age and gender groups.

As expected, from the analysis of the centroids, in countries with low death rates and mild social restrictions (C1), both the emerging adults and young adults did not show a high level of fear, but felt the lack of companionship, especially in the case of men; at the same time, middle-aged and older women showed a higher level of fear and lower lack of companionship. Conversely, people from high death rate countries and

harsh restrictions (C2) experienced a higher fear of COVID-19, without feeling the lack of companionship. Furthermore, middle-aged men and young adult women felt both the lack of companionship and being left out. These results are not surprising if we consider that during the time-lag of the survey, Italy and Spain underwent strict restrictions and lockdown, which could have impacted on the people's sense of loneliness. Moreover, Italy and Spain registered over 10,000 deaths in the two weeks of the survey alone, while Bosnia and Herzegovina, Slovenia, Slovakia, and Serbia had 160 deaths in total. Furthermore, previous data from the USA also showed that fear appeared to be concentrated in regions with the highest reported COVID-19 cases [25].

Regarding the influence of gender, our results confirmed that women reported greater fear than men both in C1 and C2 countries. This finding is consistent with literature showing that females may be more vulnerable to developing psychosocial distress during the pandemic [6,8]. Research on the impact of COVID-19 pandemic on men's and women's well-being treated separately is still scarce and there is a need to tackle gender equality in any decision making for the COVID-19 [39]. The findings of the current study suggest that the discriminant functions can be used to identify sub-groups at high risk of distress during the COVID-19 pandemic. The elderly females from countries with low death rate could be considered a group at moderate risk of excessive fear of COVID-19 and lack of companionship. Given the mild restrictions imposed in these countries, this vulnerable group could be supported by regular exercising and maintaining a healthy diet pattern to help prevent symptoms of stress during the pandemic.

Of note, in Italy and Spain, older men (who are at a higher risk of COVID-19 complications) represent a class of individuals at risk of a high fear of COVID-19 and feelings of social isolation. From a policymaking perspective, more attention should be paid to these vulnerable groups by enhancing on-line health services and support. Moreover, these vulnerable groups should be helped in avoiding potentially false reports and continually checking COVID-19 related news, in order to alleviate their feelings of fear and anxiety.

The COVID-19 outbreak is likely to worsen the individual's perception of loneliness by reducing social interactions and contacts [29]. Given that loneliness is a risk to physical and mental health, there has been a call for a public health framework to tackle loneliness during COVID-19, especially in older adults [40,41]. Our results showed that the older male group in Italy and Spain felt isolated from others and felt the lack of companionship more often. They also reported a higher fear of COVID-19 than other age groups. Thus, they may be identified as a sub-group at high risk of social distress during the COVID-19 pandemic [40]. Overall, the results of this study, which was conducted during the first wave of the COVID-19 pandemic, indicate multiple correlations between fear of COVID-19 and feelings of loneliness, with socio-demographic characteristics of individuals on the one hand and epidemiological emergency measures at the state level on the other. Therefore, they point to the need for more detailed research, with a focus on gender, generation, or socio-economic groups. For example, a cross-cohort study from the UK reported that young adults, people with a lower education and income, and people living alone had a higher risk of being lonely [42]. Further research is necessary to examine whether the accumulation of multiple risk factors can impact on loneliness levels across different European countries. Physicians could help lonely adults to use social services and community-based organizations, and support them in alleviating loneliness and addressing essential needs [43]. Our results showed that females in C1 countries felt isolated from others and with a lack of companionship more often than males. It could be speculated that in countries with mild social restrictions following the COVID-19 outbreak, women were more fully engaged with demanding family activities than men and had less opportunities for social interactions, thus feeling lonelier at this difficult time.

Strengths and Limitations of the Study

The main strength of the current study is that we examined the impact of the COVID-19 outbreak on fear and the sense of loneliness in a large sample of populations from

different European countries. This study also has several limitations. First, the study relies on cross-sectional data, which were collected during the first wave of the pandemic. Further research is needed to examine how the levels of fear of COVID-19 and loneliness changed over time. Second, limitations of the study exist in terms of the self-selective nature of participation in this online study. Furthermore, the recruiting per country resulted as unbalanced. There is evidence that disadvantages of online and single wave approach are a low control over the sample and response rates from low to modest, which can result in an unbalanced structure of the sample [44–46]. Further research is necessary to replicate these findings with balanced and representative samples of the general population. Moreover, well-educated people are more likely to participate in an on-line survey than the less-educated, as confirmed by Smith [47], and people of a low socioeconomic status might not be provided with the internet and IT technology. Third, the fear of COVID-19 represents a novel construct and the importance and validity of this variable remains unknown [16]. Moreover, the fear of COVID-19 scale was not fully validated for some of the languages used in the current study and further research is warranted to test its cross-country measurement invariance. Finally, due to the demands of social desirability, using self-report measures may not reflect people's real opinions and feelings [47].

5. Conclusions

Overall, our results show that people from European countries with a high number of infections and deaths during the COVID-19 pandemic reported different levels of fear and feelings of loneliness than people from countries with very low death and infection rates. Our findings support calls for the countries involved to monitor over time the long-term effects of the COVID-19 pandemic on the individual's levels of fear and loneliness, given the rise of infections and deaths in the second half of 2020. Moreover, our results highlight the fact that future research on the negative health consequences of the COVID-19 pandemic should examine different age and gender groups separately in order to assess which groups might be more vulnerable and, consequently, to take actions to help those at most risk. Analysis of emotional well-being in groups at risk (with mental health issues), may help to lessen the long term social and economic costs due to the COVID-19 outbreak, and integrate behavioral health expertise into public health responses to the pandemic [48–50].

Future research on the negative health consequences of the pandemic can build on the cross-country studies that adopted the fear of COVID scale in several European countries, such as Italy, Spain, Israel, Norway, and Russia [51–55], which have consistently supported the importance of assessing the fear of COVID as a relevant clinical outcome among the general population, in order to assist decision-makers and health practitioners to screen the most vulnerable groups.

Supplementary Materials: The following are available online at https://www.mdpi.com/1660-4601/18/5/2586/s1, Table S1: Descriptive statistics of the results of the survey, Table S2: Descriptive statistics of the results by countries, Figure S1: COMULATIVE DEATHS CASES DURING THE SURVEY (15–28 April 2020)

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