Interlimb Coordination, Strength, and Power in Soccer Players Across the Lifespan

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Abstract

Cortis, C, Tessitore, A, Perroni, F, Lupo, C, Pesce, C, Ammendolia, A, and Capranica, L. Interlimb coordination, strength, and power in soccer players across the lifespan. *J Strength Cond Res* 23(9): 2458–2466, 2009—This study aimed at verifying whether chronic participation in soccer training has a beneficial effect ($p < 0.05$) on the improvement and the maintenance of interlimb coordination performance across the lifespan and whether coordination is moderated by strength and power performances. Forty young (12 ± 1 yr), 42 adult (26 ±5 yr), and 32 older (59 ± 11 yr) male soccer players and sedentary individuals were administered in-phase (IP) and antiphase (AP) synchronized (80, 120, and 180 bpm) hand and foot flexions and extensions, handgrip and countermovement jump (CMJ) tests. Regardless of age, soccer players always showed better performances (handgrip: 383 ± 140 N; CMJ: 28.3 ± 8.7 cm; IP: 55.2 ± 12.9 s; and AP: 31.8 ± 25.0 s) than sedentary individuals (handgrip: 313 ± 124 N; CMJ: 21.0 ± 9.4 cm; IP: 46.7 ± 20.2 s, and AP: 21.1 ± 23.9 s). With respect to IP and AP performances, a hierarchical model ($p < 0.0001$) emerged for CMJ, explaining 30% and 26% of the variance for IP and AP, respectively. In contrast, handgrip did not provide increments in the explained variance. Results indicate that chronic soccer training is beneficial to develop strength, CMJ, and interlimb synchronization capabilities in children, to reach higher levels of proficiency in adults, and to maintain performance in older individuals. The predicted role of CMJ on interlimb coordination indicates that a fine neuromuscular activation timing is central for both jump and coordinative performances. In practice, to induce higher attentional control and executive function in open skill sport athletes and to better prepare players to cope with the demands of their match, coaches should modulate complex motor behaviors with increasing velocity of execution and are strongly recommended to make use of technical and tactical drills that focus on the player's agility under time pressure to induce higher attentional control and executive function.

Key Words Homolateral hand and foot coordination, older individual, field evaluation, handgrip, vertical jump

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Introduction

Soccer is one of the most popular sports in the world, played at all levels and ages. Scientific information is provided on fitness level of players (3,42) and the technical aspects, activity profiles, and physiologic load of soccer matches played by adult (3,25,38), young (5,8), and older players (42). During a soccer match, players perform several dynamic movements (i.e., kicks, sprints, tackling, jumps), which require high strength and power of leg muscles (17), proper timing, and transfer of energy between segments. Much research has stressed the importance of fine multijoint control to improve soccer performance (17,19), suggesting that neural coordination should be trained to improve the player's abilities.

In the literature (1,2,11,12,23,30,32,44), the laws that regulate multilimb coordination patterns have been studied in laboratory settings by manipulating the movement directions and frequencies of the hand and foot. Results showed that movement constraints of coordinative tasks are influenced by movement direction, with the isodirectional mode (i.e., in-phase [IP]) being less difficult to perform than the nonisodirectional (i.e., antiphase [AP]) and velocity of execution, with faster executions being more difficult to be maintained than slower. In particular, phase transitions (i.e., from AP to IP coordination) occur when the foot fails to mirror the movement of the hand (1). Because the coupling of hand and foot movements is not completely mature by the end of the first decade of life (9,12) and dramatically decreases in relation to advancing age (9,30) and hemiplegy (2), a relationship between interlimb coordination and strength has been hypothesized (2,10). In fact, strength is often recognized as a relevant factor in the performance of motor skills, becoming even more important as individuals age (36,39). To evaluate the capacity of the active muscles, assessments of static or dynamic strength are usually performed. More than static strength, the interaction between force of contraction and speed of movement (i.e., power) appears to be effective in representing neuromuscular changes in older individuals (36). Typically, overall static strength and functional power of lower limbs are evaluated from handgrip and countermovement jump (CMJ) performances, the latter being greatly dependent on proper timing (6). Thus, it might be hypothesized that complex coordinative tasks such as synchronized hand and foot movements and CMJ share common demands of adequacy of temporal parameters rather than isometric strength. However, no study has evaluated this issue across the lifespan as also related to sport practice. In considering that higher values in muscle power of the lower limbs have been reported in elite (18), young (7), and old (42) players, it could be also hypothesized that soccer training enhances interlimb coordination abilities of young and elite players and preserves them from age-related deterioration in older players.

Therefore, the aims of the present study were to investigate a) the effects of soccer training on interlimb coordination, strength, and power performances across the lifespan, and b) whether interlimb coordination is predicted by strength and power performances and this relation is moderated by age and expertise.

Methods

Experimental Approach to the Problem

Although soccer strongly depends on the player's capability to finely control his/her foot, neuromuscular control and the function of players are frequently evaluated only by means of strength and muscular power of the lower limbs. The present study was designed to investigate the relationship between age, soccer training, interlimb coordination, strength, and power. To include a large sample of soccer players and sedentary individuals of different ages and to limit the cost and complexity of instrumental monitoring, a field-based approach was preferred.

Recently, a field interlimb coordination test has been validated in children, adults, and older individuals using the time of correct execution as the main dependent variable (9). This parameter showed high test-retest stability coefficients for both IP (intraclass correlation coefficients [ICCs] = 0.95–0.96) and AP (ICCs = 0.72–0.98) data (9) and proved also to be a excellent tool in discerning the effects of sport practice in older individuals (10). The overall strength and functional power of the lower limbs were assessed by means of isometric grip strength (31,39,43) and CMJ (34,41,42), respectively. Handgrip performances showed high (range: 0.96–0.98) test-retest ICCs for young (14), adult, and old individuals (28), respectively. Also, CMJ performances showed high ICCs (range: 0.80–0.98) for male individuals (34) and team sport players (41).

Participants were administered the 3 tests in a randomized, counterbalanced order, and measurements were conducted at the same time of the day to minimize the effect of diurnal variations on the selected parameters. To evaluate the main effects of strength (i.e., handgrip performances) and power (i.e., CMJ) predictors on interlimb coordination performances, a hierarchical regression was used before estimating any effect a predictor could exert jointly with the potential moderating factors (i.e., age and soccer expertise).

Subjects

The local institutional research committee approved this study. Written information and oral instruction were given to 57 male soccer players (20 young: 12 $\pm$ 1 yr; 21 adults: 27 $\pm$ 5 yr; 16 old individuals: 58 $\pm$ 10 yr) and 57 co-aged sedentary individuals (20 young: 12 $\pm$ 1 yr; 21 adults: 24 $\pm$ 3 yr; 16 old individuals: 59 $\pm$ 11 yr), who provided their written consent of participation. Parental consent was obtained for children. Young players had at least 4 years of previous soccer training (two 2-hr training sessions weekly) and currently trained for two 2-hour weekly sessions and a weekly competitive match. Adult players had at least 10 years of previous soccer training (four 1.5-hr training sessions weekly) and currently trained for five 2-hour weekly sessions and a weekly competitive match at professional level (i.e., Italian third league championship). Older players declared that they maintained a soccer training regimen consisting of two 1.5-hour weekly sessions and a friendly match for the previous 10 years. Sedentary individuals did not attend any training program for the previous 5 years. Criteria for inclusion in the study was the absence of the following conditions: evidence or known history of neuromuscular disorder, cognitive impairment, wrist or ankle arthritis, use of medications able to affect the test performance, or injury to the wrist or ankle during the previous 6 months.

Procedures

In determining preferred body side, hand preference was not considered valid because older individuals might have experienced a parent's or school officials' intolerance regarding their left-hand preference during childhood. Thus, they might have shifted toward a preferred use of the right hand (36). Because, with increasing age, coordination deteriorates less with use, there could be a greater discrepancy between the use of the preferred and nonpreferred hand than that of the preferred and nonpreferred leg. Thus, as seen in the literature (9), the preferred leg of the participants was considered more appropriate to mirror the individual's body side preference. Furthermore, because no significant differences between body sides emerged while evaluating interlimb coordination performances (9,10), only the data concerning preferred body side were collected for this parameter.

At the beginning of the experiment, participants were seated on a table with elbows and knees flexed at 90°. The

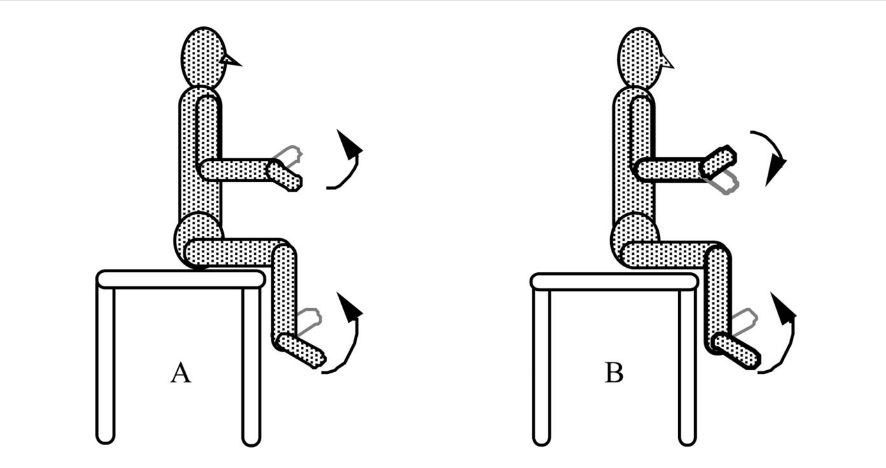

Figure 1. Schema of A) in-phase coordination mode (associations of wrist extension with ankle dorsal flexion and wrist flexion with ankle plantar flexion) and B) antiphase coordination mode (association of wrist flexion with ankle dorsal flexion and wrist extension with ankle plantar flexion).

position allowed independent motion of the hands and lower limbs in the sagittal plane. Shoes had been previously removed to avoid additional loading of the legs. Participants had to perform flexion and extension movements around the wrist and ankle joints at a 1:1 ratio. Participants were instructed to make cyclic homolateral hand and foot movements in a continuous fashion for the total duration of a trial (60 s) and to preserve spatial and temporal requirements of the movement patterns. The experimental condition was tested in 2 coordination modes (Figure 1): IP mode (i.e., associations of hand extension with foot dorsal flexion and hand flexion with foot plantar flexion) and AP mode (i.e., association of hand flexion with foot dorsal flexion and hand extension with foot plantar flexion).

Each test condition was performed at 3 frequencies (80, 120, and 180 bpm), as dictated by a metronome. A 2-minute rest was given between test conditions. During these pauses, the participants were allowed to stand. The order of trials was counterbalanced across participants among coordination modes. After 15 seconds of the required metronome pace, a "ready-go" command led to the start of a trial. Using a stopwatch, an observer measured the time of correct execution(s) of the homolateral hand and foot coordination, that is, the time from the beginning of the movement up to when the individual failed to meet either the spatial or the temporal task requirements. To avoid disagreement among observers, a single competent observer scored the performances. Before the experiment, the observer's intra-individual reliability coefficients were assessed through video-recording evaluations (range: 0.89–0.95).

Grip strength was measured using a mechanical handgrip dynamometer (Lode, Groningen, The Netherlands). The Lode handgrip dynamometer consists of an ergonomically formed measuring beam (range 0–1,000 N) connected to an amplifier. The force exerted on the strain gauges is displayed online. Before the test, the grip width was individually adjusted to achieve a 90° angle with the proximal-middle phalanges. Each participant stood upright with his arm vertical and the measuring beam close to the body. The maximal peak pressure (expressed in N) was recorded for a set of 2 contractions. The participants were asked to make the strongest grip possible, and verbal encouragement was given each time to obtain their maximal score. Two trials, with a 1-minute pause in between, were allowed for each handgrip, and the highest value was used for statistical analysis.

Jump performances were evaluated by means of an optical acquisition system (Optojump, Microgate, Udine, Italy) developed to measure with 10^{-3} s precision all flying and ground contact times. The Optojump photocells are placed at 6 mm from the ground and are triggered by the feet of the participant at the instant of take-off and are stopped at the instant of contact upon landing. Then,

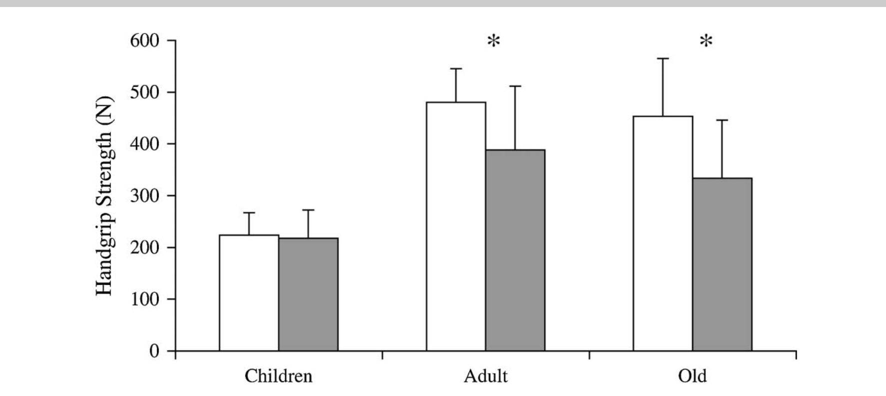

Figure 2. Mean and *SD* of handgrip performances in children, adult, and older soccer players and sedentary individuals. *$p < 0.05$.

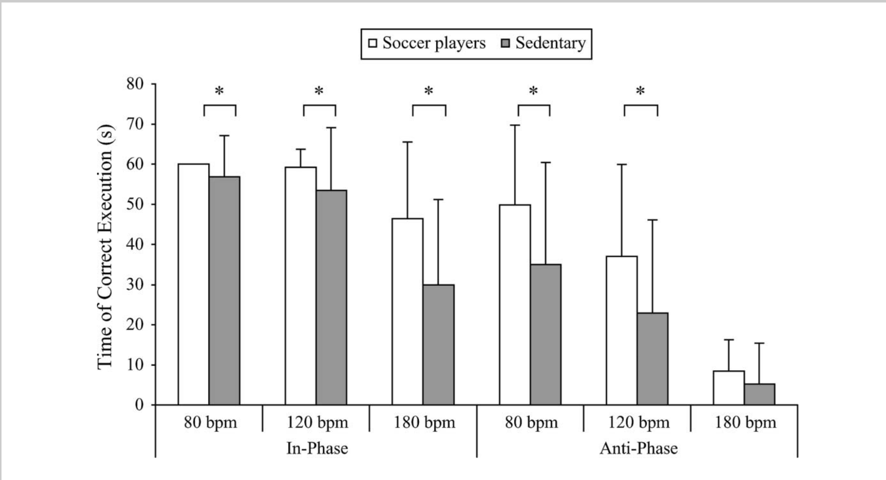

Figure 3. Mean time of correct execution of in-phase and antiphase homolateral hand and foot coordination performances at 3 execution frequencies (80, 120, and 180 bpm) in soccer players and sedentary individuals. $^*p < 0.05$.

calculations of the height of the jump are made. From the standing position, the participants were required to bend their knees to a freely chosen angle, which was followed by a maximal vertical thrust. The effect of the arm swings was minimized by requesting the athletes to keep their hands on their hips. Because it was assumed that participants maintained the same position at take-off and landing, they were instructed to keep their body vertical throughout the jump and to land with knees fully extended. Any CMJ that was perceived to deviate from the required instructions was repeated. Participants were allowed 2 trials with a 5-minute recovery period between trials. Thus, their best CMJ performance was used for statistical analyses.

Statistical Analyses

Means and *SD*s have been calculated for each studied parameter, and an alpha level of 0.05 was selected throughout the study. A 2 (Soccer Expertise: soccer players and sedentary individuals) × 3 (Ages: children, adult, and older individuals) analysis of variance (ANOVA) was applied to jump (cm) and handgrip (N) performances, whereas a 2 (Soccer Expertise: soccer players and sedentary individuals) × 3 (Age: children, adult, and older individuals) × 2 (Coordination Mode: IP, AP) × 3 (Execution Frequency: 80, 120, and 180 bpm) ANOVA with repeated measures was applied to the time(s) of correct execution of the interlimb coordination test. If the overall *F*-test was significant, post hoc Fisher protected least significant difference comparisons with Bonferroni corrections were used. To provide meaningful analysis for comparisons from small groups, the Cohen's effect sizes (ES) between groups were also calculated (15), considering ES 0.2 or less trivial, from 0.3 to 0.6 small, less than 1.2 moderate, and greater than 1.2 large.

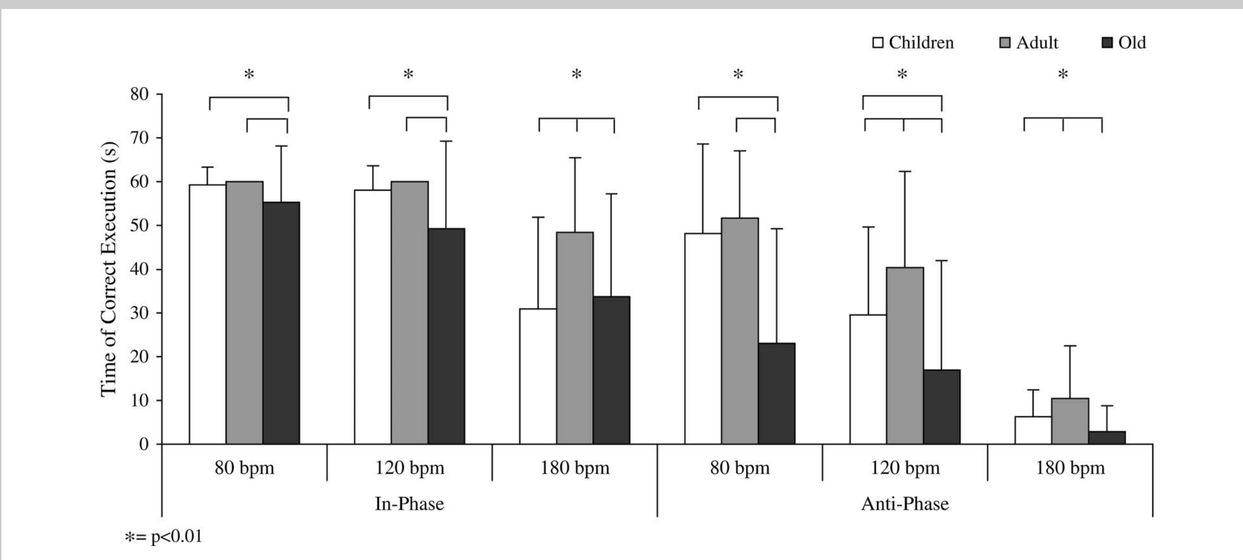

Figure 4. Mean time of correct execution of in-phase and antiphase homolateral hand and foot coordination performances at 3 execution frequencies (80, 120, and 180 bpm) in children, adults, and older individuals.

Table 1. Percentages of the differences between soccer players and sedentary group means.

	Differences (%)		
	Children	Adults	Older Individuals
Hand grip	3	19	26
CMJ	22	22	41
In-phase coordination (80 bpm)	3	0	16
In-phase coordination (120 bpm)	4	0	30
In-phase coordination (180 bpm)	41	38	22
Antiphase coordination (80 bpm)	14	25	70
Antiphase coordination (120 bpm)	38	14	86
Antiphase coordination (180 bpm)	42	13	97

To test whether CMJ and handgrip performances are predictors of interlimb coordination and whether this relation is moderated by age and expertise, we conducted 2 hierarchical regression analyses with IP and AP performances as dependent variables, respectively. To obtain a single value for each coordination mode, we computed the number of movements to be performed per second (mov/s) for each frequency of execution (1.3 mov/s at 80 bpm, 2 mov/s at 120 bpm, and 3 mov/s at 180 bpm). Then, we calculated the individual number of correct movements executed at 80, 120, and 180 bpm and summed them to pool data across execution frequencies separately for IP and AP coordination.

A stepwise-forward method involving 3 hierarchical regression blocks was used. First, coordination (i.e., IP or AP) was independently predicted by the main effects accrued by Handgrip and CMJ (Block 1). Then, the interactive effects created by multiplying the factors Handgrip and CMJ with Age (Block 2) and Soccer Expertise (Block 3) were estimated. The order of entry of the factors in Block 2 and 3 was selected to evaluate the moderating effects of Soccer Expertise after controlling statistically for the prediction accrued by Age and its interaction with CMJ and Handgrip, avoiding the possibility that eventual effects of Soccer Expertise might merely reflect a covariation with Age. Overall, the presence of statistically significant regression effects for any of the 4 interaction terms included in Blocks 2 to 3 would prove that the relations between IP-AP and CMJ or Handgrip were differently moderated by Age and Soccer Expertise. A Pearson test was applied to evaluate correlation between variables in the case of significant effects of the predictors in the regression model.

Results

Figure 2 shows the handgrip performances of soccer players and sedentary individuals for the 3 age classes. A main effect was found for Age ($p < 0.0001$, ES = 0.2–0.8), Soccer Expertise ($p < 0.0001$, ES = 0.3), and their interaction ($p = 0.02$). Performances were better in soccer players (383 ± 140 N, range: 167–686 N) and worst in sedentary (313 ± 124 N, range: 154–630 N) individuals, with children (221 ± 49 N, range: 154–377 N) significantly ($p < 0.0001$) different from

Table 2. Hierarchical multiple regression analysis model of in-phase (IP) inter-limb coordination as a function of Countermovement jump (CMJ), handgrip (HG) performances, age and soccer expertise factors.

	Block 1			Block 2			Block 3		
Factors	Beta	*t*	*p*	Beta	*t*	*p*	Beta	*t*	*p*
CMJ	0.54	6.81	<0.0001						
HG	0.44	1.18	NS						
CMJ × Age				−0.06	−0.20	NS			
HG × Age				0.14	0.72	NS			
CMJ × Soccer Expertise							0.09	0.34	NS
HG × Soccer Expertise							0.12	0.44	NS
R^2 change	0.29			0.01			0.03		
F ratio for R^2 change	46.39			0.87			2.01		
p	<0.0001			0.42			0.14		
Total R^2	0.33								
Adjusted R^2	0.30								

Table 3. Hierarchical multiple regression analysis model of antiphase (AP) inter-limb coordination as a function of countermovement jump (CMJ), handgrip (HG) performances, age and soccer expertise factors.

	Block 1			Block 2			Block 3		
Factors	Beta	*t*	*p*	Beta	*t*	*p*	Beta	*t*	*p*
CMJ	0.49	5.90	<0.0001						
HG	0.05	0.12	NS						
CMJ × Age				−0.31	−1.02	NS			
HG × Age				0.06	0.30	NS			
CMJ × Soccer Expertise							−0.31	−1.15	NS
HG × Soccer Expertise							0.49	1.79	NS
R^2 change	0.24				0.02		0.03		
F ratio for R^2 change	34.82				1.66		2.48		
p	<0.0001				0.19		0.09		
Total R^2	0.29								
Adjusted R^2	0.26								

adult (434 ± 108 N, range: 174–630 N) and older (394 ± 126 N, range: 199–686 N) individuals. Post hoc analysis for the Age × Soccer Expertise interaction showed differences only in adults ($p = 0.004$) and older ($p = 0.005$) individuals.

Countermovement performances showed main effects for Age ($p < 0.0001$, ES = 0.4–0.8) and Soccer Expertise ($p < 0.0001$, ES = 0.4). Performances were best in soccer players (28.3 ± 8.7 cm, range: 11.9–47.8 cm) and worst in sedentary (21.0 ± 9.4 cm, range: 4.4–42.3 cm) individuals. Post hoc analysis of the age effect showed worst performances of older individuals (16.0 ± 7.4 cm, range: 4.4–30.9 cm), with respect to children (22.0 ± 5.0 cm, range: 9.7–28.7 cm) and adults (33.7 ± 6.9 cm, range: 17.1–47.8 cm), with all groups being significant.

Interlimb coordination showed main effects for Age ($p < 0.0001$, ES = 0.2–0.3), Soccer Expertise ($p < 0.0001$, ES = 0.2), Coordination Mode ($p < 0.0001$), Execution Frequency ($p < 0.0001$), and the interactions Coordination Mode × Age ($p = 0.005$), Execution Frequency × Age ($p < 0.0001$), Coordination Mode × Execution Frequency ($p < 0.0001$), Execution Frequency × Age × Soccer Expertise ($p < 0.0001$), Coordination Mode × Execution Frequency × Soccer Expertise ($p < 0.0001$), and Coordination Mode × Execution Frequency × Age ($p < 0.0001$). As expected, correct executions were better during the IP condition (51.0 ± 17.4 s, range: 0–60 s) than AP (26.4 ± 25.0 s, range: 0–60 s), with a significant decrement between frequencies (80 bpm: 50.4 ± 19.4 s, range: 0–60 s; 120 bpm: 43.2 ± 23.0 s, range: 0–60 s; 180 bpm: 22.5±22.9 s, range: 0–60 s). Soccer players showed better performances (43.5 ± 23.0 s, range: 0–60 s) than their sedentary counterparts (33.9 ± 25.6 s, range: 0–60 s). Performances were worst in older individuals (30.2 ± 27.1 s, range: 0–60 s), intermediate in children (38.7 ± 23.9 s, range: 0–60 s), and best in adults (45.2 ± 21.8 s, range: 5–60 s), with all age groups being significant. Regarding Soccer Expertise (Figure 3), post hoc analysis of the IP performances showed differences at all execution frequencies (80 bpm: $p = 0.02$; 120 bpm: $p = 0.008$; 180 bpm: $p < 0.0001$), whereas AP performances differed only at 80 bpm ($p = 0.0007$) and 120 bpm ($p = 0.001$). Regarding age (Figure 4), post hoc analysis of IP performances showed differences (80 bpm: $p = 0.02$; 120 bpm: $p = 0.0002$; 180 bpm: $p = 0.0003$) between adult and older individuals at each frequency of execution, whereas children differed from older individuals only at 80 bpm and 120 bpm and with adults at 180 bpm. In the AP mode, older individuals always differed from adults for the AP performances, whereas at 120 bpm, differences ($p < 0.0001$) were found between all age groups. At 80 bpm, a difference ($p < 0.0001$) emerged also between children and older individuals, whereas at 180 bpm ($p = 0.002$), differences emerged only between adults and children.

Correlation Between Interlimb Coordination, Strength, and Power Performances

To provide meaningful information on the role of Soccer Expertise in determining handgrip, jump, and interlimb coordination performances, Table 1 reports the percentages of decrements calculated for each age group. Differences between age and activity groups were low in adults (range: 0–38%), high in older individuals (range: 16–97%), and intermediate in children (range: 3–42%). Differences between co-aged groups were more evident in the AP interlimb coordination performances at the highest frequency of execution (range: 13–97%).

To estimate the main and joint effects of CMJ and handgrip on coordination performances, two 3-block hierarchical regressions were initially performed for IP coordination and AP coordination, respectively. Significant effects ($p < 0.001$)

at each step were found for both IP (Block 1: $p < 0.0001$, Block 2: $p < 0.0001$, Block 3: $p < 0.0001$) and AP (Block 1: $p < 0.0001$, Block 2: $p < 0.0001$, Block 3: $p < 0.0001$) coordination.

Tables 2 and 3 show the predictors' significant regression coefficients and the amount of variance explained (R^2 and adjusted R^2) associated with each regression block. The hierarchical regression yielded a statistically significant model of CMJ effect at Block 1 for IP ($r = 0.5$, $p < 0.0001$) and AP ($r = 0.5$, $p < 0.0001$) coordination, whereas Handgrip did not provide significant increments in the explained variance. Overall, the final model significantly explained 30% and 26% of the variance for IP and AP, respectively.

Discussion

This study aimed at verifying whether chronic participation in soccer training has a beneficial effect for the improvement and the maintenance of interlimb coordination performance across the lifespan and whether coordination is moderated by strength and power performances. However, several caveats have to be considered when comparing performance of young, adult, and older soccer players. In fact, the training regimen of the 3 age groups is quite different in frequency, intensity, duration, and objectives. Usually, coaches plan 2 sessions weekly to train the soccer technical skills of young players. At a professional level, 5 to 7 training sessions are scheduled weekly, with physical trainers aiming at maintaining physical capabilities of players and head coaches focusing on the technical and tactical aspects of the team. Conversely, senior soccer players train without a coach twice a week, aiming at entertaining themselves while maintaining their fitness.

The present results confirm that interlimb coordination depends on exercise mode and frequency of execution, with better performances shown on isodirectional tasks and at slower execution frequencies that require a lower level of attentional monitoring (9,10,21,33). In accord with the literature concerning the age-related "parabola" of coordinative development and degradation (9,24,36), interlimb coordination performance was best in adults, intermediate in children, and worst in older individuals, with age-related performance decrements more pronounced during AP and faster movements that need increased attentional allocation to inhibit the natural IP mode (45). Furthermore, this test succeeded in discriminating coordination performances between soccer and sedentary individuals of different ages, contributing to the understanding of the effects of training on movement coordination in the lifespan.

For the IP condition, a significant difference emerged for soccer expertise and frequency of execution for all age groups, indicating that soccer practice can improve even the more natural interlimb coordination pattern in children, adults, and old individuals. In particular, with increasing velocity of execution, the elite soccer players did not show any decrement in performance. This phenomenon reflects the higher coordination of professional players, who also undergo a more demanding training regimen than young and amateur older players. The positive effects of chronic soccer training become more intriguing when comparing the performance of young and older soccer players with that of sedentary adults. In fact, young soccer players show almost the same times of correct executions observed in the sedentary adults, whereas old soccer players showed even better performances at 180 bpm. Also, in the AP condition, soccer players always showed significantly better performances than sedentary counterparts, indicating that chronic soccer practice helps players to overrule the easier movement patterns, which spontaneously emerge under stressful conditions or during the acquisition of new skills (19). These results are in line with the literature that showed high attentional control (29) and executive inhibitory function (16) in athletes practicing open skill sports.

There is the evidence that homolateral hand and foot coordination is reduced in older individuals (9,33) because of the combined effects of aging and a sedentary lifestyle (10,24,36). In line with the literature on older trained individuals (10), older soccer players did not show the dramatic decrement at all frequencies of execution found in the co-aged sedentary individuals, indicating that regular and prolonged practice of soccer counteracts the degradation of interlimb coordination performance with increasing age. Thus, the fact that older soccer players are better able to maintain AP coordination than their sedentary counterparts might be a result of the combined beneficial effects of both the coordinative demands and the aerobic-anaerobic components of their training, which exert a preservative effect on the efficiency of those executive attentional processes involved in the control of complex motor behaviour (4). On the other hand, the decrement of interlimb performance of older players with respect to young and adult players might be a result of the fact that older athletes train less frequently and intensively than younger and do not benefit from the technical support of a coach who focuses on the enhancement of both the quality of movements and physical capabilities of athletes (42).

Grip strength is considered a measure of muscle function (31) and is used also to study the development in children (43) and the effects of aging in human populations (20). Also, the CMJ is considered a measure of functional performance (26,35,37) and is widely used to evaluate soccer players (13,22,27,40). Varying as a function of age, grip strength and CMJ scores develop from childhood, peak around the second decade of life, and decrease in older individuals. In line with the literature (36), marked differences in handgrip and CMJ were observed as a function of age, with older individuals maintaining better grip strength performances. Although soccer training appears not to influence grip strength in children, it was very effective in the other age groups. In particular, older players showed higher values with respect to their co-aged (26%) and adult (17%) sedentary counterparts. On the other hand, the marked decline in power and interlimb performances indicates that higher levels of neuromuscular timing and control are required to perform dynamic movements of lower limbs with respect to the simple isometric test of upper-body muscle strength. Because many factors have deleterious effects on central coordination and control of dynamic movements, focusing training on high-velocity activities should be considered essential for increasing functional fitness in older ages (36). In fact, whereas young and professional soccer players showed similar percentages of increment (22%) with respect to their relative sedentary counterparts, a 41% difference was observed between older players and sedentary individuals. Therefore, soccer proved to be beneficial not only to develop synchronization capabilities in children and to reach higher levels of proficiency in adults, but it also maintained central and peripheral factors in older individuals. In particular, soccer training enables older individuals to efficiently cope with high coordinative demands, which may be relevant to prevent loss of capacity and deal with everyday functions, thus enhancing independency and quality of life.

Several authors (2,10) have speculated a relationship between strength and interlimb coordination. In the present study, only CMJ proved to be a good predictor of co-ordination in both IP and AP mode, explaining approximately 30% of the variance. These results indicate that strength cannot per se be a relevant factor in determining better performances of coordination, whereas fine neuromuscular activation timing is central for both CMJ (6) and hand-foot coordination (1,30) performances. Furthermore, the lack of a moderating effect of age and soccer expertise might indicate that CMJ has the same predictor activity across the lifespan. However, some caveats have to be taken into account in cross-sectional studies. In fact, the individual variables of interest (i.e., sport-specific expertise and motor coordination skill) may be confounded by cohort effects because of the limited sample size and the effects of the differences in sociocultural variables that may influence coordination performance.

Practical Applications

Soccer coaches are strongly recommended to make use of technical and tactical drills that focus on the player's agility under time pressure to induce higher attentional control and executive function. In fact, increasing velocity of execution strongly affects the attentional level and coordination abilities of individuals. In considering that coordinative performances tend to decrease as a result of fatigue, coaches should include technical tactical agility drills toward the end of the training session to better prepare players to cope with match demands.

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