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Research article

Jump Rope Training: Balance and Motor Coordination in Preadolescent Soccer Players

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Abstract
General physical practice and multidimensional exercises are essential elements that allow young athletes to enhance their coordinative traits, balance, and strength and power levels, which are linked to the learning soccer-specific skills. Jumping rope is a widely-used and non-specific practical method for the development of athletic conditioning, balance and coordination in several disciplines. Thus, the aim of this study was to investigate the effects of a short-term training protocol including jumping rope (JR) exercises on motor abilities and body balance in young soccer players. Twenty-four preadolescent soccer players were recruited and placed in two different groups. In the Experimental group (EG), children performed JR training at the beginning of the training session. The control group (CG), executed soccer specific drills. Harre circuit test (HCT) and Lower Quarter Y balance test (YBT-LQ) were selected to evaluate participant's motor ability (e.g. ability to perform rapidly a course with different physical tasks such as somersault and passages above/below obstacles) and to assess unilateral dynamic lower limb balance after 8 weeks of training. Statistical analysis consisted of paired t-test and mixed analysis of variance scores to determine any significant interactions. Children who performed jumping rope exercises showed a significant decrease of 9% ($p < 0.01$, ES = 0.50-0.80) in the performance time of HCT. With regard to the CG, no differences were highlighted ($p > 0.05$, ES = 0.05-0.2) from pre- to post-training. A training-by-group interaction was found for the composite score in both legs ($p < 0.05$, Part $\eta^2 > 0.14$). Our findings demonstrated that JR practice within regular soccer training enhanced general motor coordination and balance in preadolescent soccer players. Therefore, the inclusion of JR practice within regular soccer training session should encouraged to improve children's motor skills.

Key words: Muscle power, plyometric exercise, postural control, motor skills, deliberate practice.

Introduction

Predicting long-term achievement of young players turns problematic because of multifactorial determinants of the success (e.g. motivation, maturation, environmental regulating factors) (Carling et al., 2009). However, it is recognized that athletes who are experienced with a wide range of physical activities during their motor development stages required less time of training to reach a sport-related motor-proficiency (Baker et al., 2003). For example, cross-training (i.e. training with the inclusion of other sports or activities) may improve physical fitness and physiological conditioning in children who regularly practice a specific sport (Baker et al., 2003). According to the developmental model of sports participation, during the sampling years (from 6 to 12 years) young athletes need to take part to deliberate practice and exercises that help to achieve gains in their motor abilities, rather than those exercises involving an early specialization (Côté et al., 2009). Motor abilities include perceptual and physical factors (Fleishman et al., 1984) in which many important capacities such as general motor coordination (i.e. multilimb and gross body coordination), spatial orientation, balance (i.e. gross body equilibrium), strength, and power are involved. Players with a marked motor coordination, balance and strength are likely to perform complex movements (e.g. agility tasks) with a high degree of postural control and intensity (Bobbio et al., 2009; Gordo and Gurfinkel, 2004). In soccer, although none of these elements is interchangeable, they are crucial to elevate athletes' motor abilities based on change of direction maneuvers. Hence, enhancing young soccer players' motor ability should involve the use of closed skill activities (e.g. sprinting, changing of direction and jumping), as well as open skills activities (e.g. balance, orientation tasks and reactive movements) in the form of non-specific training within regular sessions (Gabbett et al., 2008). For example, non-organized soccer activities such as game formats incorporating other sports (e.g. Handball) or relay races with and without the ball may represent useful training tools that would identify an appropriate mixture between aforementioned closed and open skills activities. However, although such activities may not include sport-specific skills, they usually refer to physical tasks that do not diversify from those regularly experienced through technical and tactical exercises (e.g. during small sided soccer games and slalom drills). Given that the involvement in various free play activities (e.g. jumping, climbing, running) is a main multidimensional stimulus in the sampling years (Côté et al., 2009), training sessions of preadolescent soccer players should also include forms of exercises that are not related to those experienced regularly.

In this context, jumping rope (JR) represents an alternative form of exercise that involves upper and lower body movements. During the execution, arms rotate the rope while legs perform repeated bounces with the aim to maintain constant vertical take-off and landing phases until the end of the exercise. During successive jumps, the body needs to re-establish balance and propulsion force through a coordinated action of upper and lower body region muscles. In particular, balance abilities are essential to obtain an effective pushing phase. The role of JR within training programs has been investigated to establish positive effects on physiological parameters of cardiovascular and respiratory systems (Hatfield et al., 1985;

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Orhan, 2013). However, several research studies also demonstrated its positive impact on physical qualities (Miyaguchi et al., 2014b; Ozer et al., 2011). Makaruk (2013) observed that performing JR during a warm up provided greater improvements in subsequent horizontal jumping tasks than a warm up protocol with traditional jumps (e.g. fast skipping and pogo jumps) in adult elite track and field athletes. Other studies also focused on the effects of JR in younger athletes. Miyaguchi et al. (2014a) investigated the use of two methods of rope jumping (i.e. basic and double under jumps) by comparing the rebound jump index as a standard indicator of the stretch-shortening cycle. The authors observed that jump rope tasks with an increased rotation frequency (e.g. in the double-under exercise) provided similar effects of plyometric rebounds in terms of a reduction in the contact time and an improvement in the jump height. Lastly, Buchheit et al. (2014) evaluated the effects of an 8-week training including short jump rope intervals (10-20 s at maximal speed with 2-3 min of passive recovery) and long jump rope intervals (2 min at 120 rotations per min with 3 min of passive recovery) on a 30-15 intermittent fitness test performance in well-trained children. The authors reported a positive impact on physiological (hearth rate and rate of perceived exertion) and performance (increase of ~9% in the final running speed test) parameters.

Despite numerous publications on various general physical capacities (i.e. running or jumping) (Miyaguchi et al., 2014b; Ozer et al., 2011; Makaruk, 2013), to date, no studies have investigated the effects of jumping rope training on coordination and balance performance in children practicing soccer. Balance and coordination, in terms of an integration of multiple physical tasks, are basic elements that allow athletes to develop a motor ability, performing movement patterns in a controlled and suitable approach. They also contribute to learn and develop more complex movements (Cordo and Gurfinkel, 2004), which play a key role in allowing young athletes to acquire sport-specific proficiency.

General motor coordination is the capacity to execute various controlled movements regardless of soccer-specific skills. Kamandulis et al., (2013) further suggest that general coordination plays a significant role in young athletes who are not able to master skills highly related to a specific sport. This statement seems to support the use of alternative forms of exercise able to improve such capacity within the sampling years. With regard to the balance, children require to maintain stability of the center of mass when performing static as well as dynamic physical activities, especially during soccer exercises. In soccer, it has been demonstrated that a higher level of competition is related to a greater balance capacity (Butler et al., 2012) across different ages. Likewise, balance capacity is widely acknowledged as a fundamental motor component (Butterfield and Loovis, 1994) in the early sampling phase.

Jumping rope performance depends mostly on the gross motor coordination that is the ability to coordinate arms, legs, and torso movements when the whole body is in motion (Fransen et al., 2012). In addition, such combined movements have the task of maintaining balance (i.e. postural stability) throughout the exercise to prevent unsuitable displacements of the center of gravity. According to these considerations, it is reasonable assume that a training program based on jumping rope exercises may be effective in improving those aforementioned capabilities. We hypothesized that a period of JR training including various motor tasks (e.g. moving the legs in a different plane and increasing the height of jumps) would be effective of improving general coordination and balance performance in children. Thus, the aim of the present study was to examine the effects of 8-week jumping rope training on general motor coordination and balance in sub-elite young soccer players. To test our hypothesis, we used the Lower Quarter Y Balance Test (YBT-LQ) for assessing dynamic postural control and the Harre Circuit test (HCT) to evaluate general coordinative traits within a wide variety of motor tasks.

Methods

Participants

Twenty-four sub-elite young soccer players (11.3±0.70 years; 48.8 ± 0.40 kg; 1.53 ± 0.05 m; soccer training experience 4.56 ± 0.66 years) participated in the study. They were training 3 times a week with the addition of one match per week. All children and their parents were informed about the purpose and experimental risks of the research. Parents or legal guardians provided the written informed consent before the investigation. A priori data and a power analysis was used to detect the sample size. The minimal number of participants required to achieve a power of 0.8 and an alpha level of 0.05 was calculated to be at least 6. The anticipated number of participants was increased to prevent an expected drop out. However, all participants were completely tested. The study was approved by the Ethical Committee of the Università degli Studi di Milano, in accordance with the Helsinki declaration as revised in 2013.

Procedures

Participants were assigned randomly to a control group (CG; n = 12) and an experimental group (EG; n = 12). The design of the study included two weeks of familiarization sessions for all physical assessments and exercises before starting the 8-week intervention program. Anthropometric characteristics were recorded 48 hours prior to testing. All participants were tested in two separate occasions with at least two days in between at the same time of day (from 3.00 pm to 5.00 pm) for both pre- and post-assessments. Testing assessments followed a random selection. The same operator supervised the testing trials and their reliability was calculated using the Intraclass Correlation Coefficient (ICC). A high value was observed in the harre circuit test tests (ICC > 0.955) and lower quarter y balance test (ICC > 0.900 for both lower limbs)

General motor coordination

General coordination competences are usually assessed utilizing tests involving layout and nature atypical of the specific sport accounted (Kamandulis et al. 2013). The Harre circuit test (HCT) is a popular and widely used test in the scientific literature (Chiodera et al., 2007; Harre, 1982; Weineck, 2009; Zatsiorsky and Kraemer, 2006) to assess the ability of a subject to coordinate quickly complex movements and general motor tasks with high dimensionality in terms of number of joints involved and levels of force generated. The scheme of the HCT was reported in the Figure 1. After an initial somersault, participants were asked to perform three consecutive passages above and below three obstacles, turning around a central cone. Three trials were performed and separated by 5 min of rest. Total time of each trial were recorded by using a photocells system (Microgate, Bolzano, Italia) and the average time was considered in the analysis. In case of mistakes (e.g. touching the obstacle), children were asked to repeat the trial after 2 minutes of rest. All trials were performed in an indoor gym, observing the same conditions.

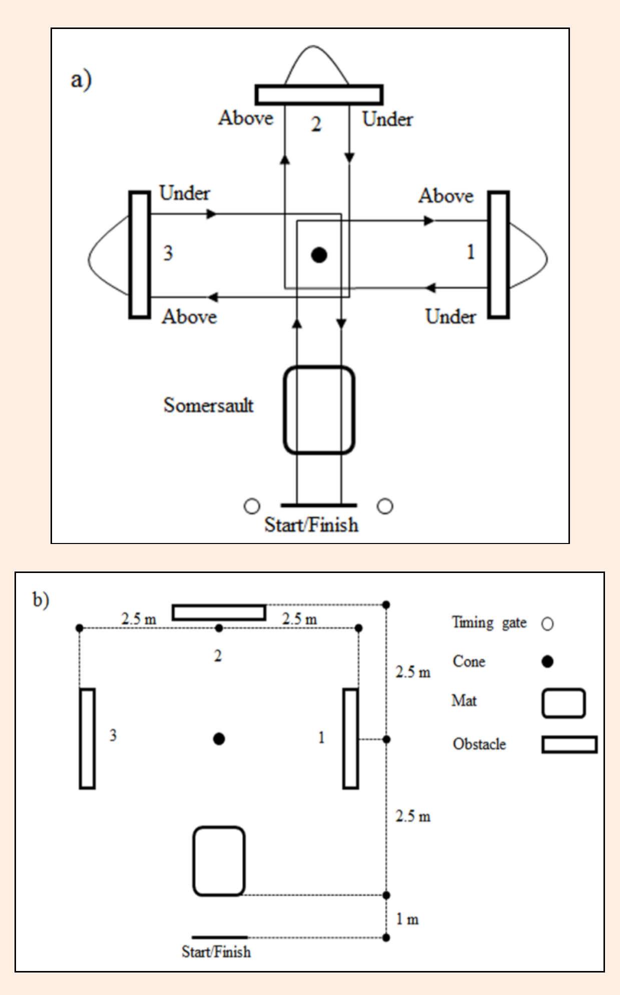

Figure 1 (a). Layout of the Harre Circuit Test. Arrows and numbers indicate the test's route to be followed as fast as possible by participants. (b). Scheme of distances among components and parts of the test.

Balance

Lower Quarter Y balance test (YBT-LQ) was included to assess unilateral dynamic lower limb balance, as a clinically efficient field test in predicting injury and performance level of soccer players (Butler et al., 2012). The YBT involved using a testing device to measure the distance reached in anterior (A), posteromedial (PM) and posterolateral (PL) direction while standing on each foot. For a complete description of the YBT device, refer to the study of Plisky et al. (2009) and Gribble et al. (2012). Children performed the YBT-LQ barefoot to limit possible influences of footwear on balance. During all trials, participants were instructed to keep the hands on their hips and not to touch the floor with the reach foot except for marking their reach. In case of a failure of the above criteria, children were asked to repeat the trial. Testing procedures consisted of three trials standing on the right foot in which participants were asked to reach the A, PM and PL direction for 3 repetitions with the opposite foot. Afterwards, equal number of trials and repetitions were performed standing on the left foot following the same order among directions.

The lower limb length was also measured to normalize the reach distance among participants (Plisky et al., 2009). From a supine position, "true" leg length were obtained by measuring the distance between the anterior superior iliac spine and the medial malleolus. From these data, the composite reach score was calculated by summing the maximum reach distance for the three reach directions (A, PM and PL) on a given limb and dividing by three times the limb length prior to multiplying by 100 to reference the composite reach as a percentage of leg length. All trials was observed and scored by an functional movement screen (FMSTM) certified operator.

Table 1. Descriptive characteristics of the JR training intervention performed by the EG.

Weeks	# sessions	TR/rest	# of sets	Rest (s)
From 1-wk to 4-wk	2	30/30	3	60
From 5-wk to 8-wk	2	40/40	3	60

sessions: Number of sessions per week; TR/rest: Training/rest per exercise; # of sets: number of sets; Rest: Rest between sets

Training groups

Children allocated in the EG, received a jump rope training program at the beginning of the soccer training session for a period of 15 min, two days a week. The entire intervention program involved 8 weeks' in-season from the beginning of October until the end of November (see Table 1). Prior to training, participants were instructed to warm up with general running exercises and dynamic stretching for ten minutes. During the jumping rope training, all the repetitions were guided by metronome rates of 120 rotations per min to ensure equal exercise intensity among children. The Jumping rope intervention consisted of 5 exercises performed with the following order: basic bounce step, double basic bounce step, alternate foot step, scissors step, and double under. Each exercise was executed by all participants using a jump rope with identical features in terms of weight (i.e. 230g), length (i.e. shoulder measurement), and material (i.e. PVC, Polyvinyl Chloride). Children located in the CG received a specific program with soccer skills. The soccer program was divided in three parts and included technical exercises (e.g. ball carrying, passing, heading, and dribbling), a combination of defensive and offensive actions (1 on 1, 2 on 1, 2 on 2 and 3 on 2), and small sided games. Each part of the program lasted 5 minutes and was performed two days a week. Every training session was conducted on an artificial turf field.

Statistical analysis

All of the analyses were performed using the IBM SPSS Statistics (v. 21, New York, U.S.A.) and data shown as mean ± SD. The Kolmogorov-Smirnov test was conducted to verify if all data met the normality test assumption. The entire data set presented a normal distribution. A paired t-test was used to determine the differences between pre-post intervention protocols on the HCT outcomes. The effect size (ES) was calculated to assess meaningfulness of differences and the thresholds for small, moderate and large effects were defined as 0.20, 0.50, and 0.80, respectively (Cohen, 1988). An alpha value of $p < 0.05$ was set as criterion level of significance. A mixed between-within subjects analysis of variance (ANOVA) was used to determine the interaction between the two independent variables of training (pre/post; within subjects factor) and group (EG and CG; between subjects factors) on the composite reach score (dependent variable) of both lower limbs, only for the YBT-LQ. Partial eta squared (Part η2) was used to estimate the magnitude of the difference within each group and the thresholds for small, moderate and large effects were defined as 0.01, 0.06, and 0.14, respectively (Cohen, 1988).

Results

Both EG and CG presented non-significant ($p > 0.05$) differences in mean age, height, and body mass. The EG obtained a significant reduction from 19.2 to 17.5 s ($p = 0.001$, ES = 0.67) in the performance time after 8 weeks of jumping rope training, while CG showed a negligible reduction from 20.1 to 19.9 s ($p = 0.226$, ES = 0.07). With regards to YBT-LQ, Table 2 shows data for composite reach score values for the two groups before and after the intervention. There a significant interaction (simple effect) found between the two groups in the pre- to post-training of the right ($p < 0.05$, Power = 0.63) and the left leg ($p < 0.05$, Power = 0.54). This indicated a significant change in scores of both legs in favor of the EG. Children located in the EG improved their composite reach score between pre- to post-training intervention (main effect) on the right limb ($p < 0.001$, Part $\eta^2 = 0.457$, Power = 0.98) and on the left ($p < 0.05$, Part $\eta^2 = 0.188$, Power = 0.58). No significant improvement was observed in the CG for both lower limbs.

Discussion

The aim of the present research was to examine the effects of short-term rope jump training on balance performance and general motor coordination in young soccer players. In the present research, motor coordination was examined by using the HCT, which evaluates the ability to coordinate quickly complex general motor tasks (e.g. climbing, hopping, running and turning) and cognitive capabilities (reaction time and spatial orientation) using the whole body (Chiodera et al., 2007). After 8 weeks of the training program, children who performed jumping rope exercises showed a significant decrease in the performance time on HCT. Conversely, children who executed soccer-specific conditioning did not reduce their running time significantly.

Inconsistent effects found in the CG, may be likely attributed to limited coordinative stimuli between upper and lower body segments within specific soccer skills. Ball carrying, passing, kicking, and dribbling represents crucial technical skills and are predominant elements within regular soccer trainings. However, technical skills are focused on specific upper and lower limbs coordinative movements (Kamandulis et al., 2013), which may not allow players in the sampling years (from 6 to 12 years) to fully benefit from general activities (Baker et al., 2003) or exercises not related with those specific skills (e.g. jumping rope exercises). Conversely, in a recent study, Hornig et al. (2014) examined the developmental sporting activities of 102 soccer players (52 professionals and 50 amateurs) and reported different conclusions. Authors stated that adult highly skilled players practiced non-organized and organized sport-specific activities (i.e. soccer match-play) for the most of the time in their childhood. However, such developmental model is too specific and can facilitate an increase in the dropout rate (Côté et al., 2009), especially in the preadolescent and adolescent stages.

In view of that, the latter statement is in line with the findings of the present study. A plausible explanation can be found on the nature of the exercise carried out by the EG. In fact, the JR motion requires a consecutive and synchronized use of both upper and lower body with a high degree of coordination and rhythmicity (Bobbio et al., 2009). The combined use of both arms and lower limbs (inter limb coordination) for such type of exercises has likely increased rhythmic and timing skills, as well as children's inter-limb coordination and gross body coordination after 8 weeks of training (Orhan, 2013). On the other hand, the greater reduction in performance time found in the EG (about 9%), may not be supported only by those enhancements, but also by an occurred muscular adaptation.

Children were asked to execute five different exercises in which were involved various steps (e.g.

Table 2. Changes in the composite score outcomes of the YBT-LQ before and after the training intervention for each group. Data are mean (±SD).

Limb	Group	Before training	After training	P	Part η2
Right	Experimental	140.50 (16.28)	144.44 (17.36) *	.025	.208
	Control	133.10 (12.99)	134.21 (11.65)		
Left	Experimental	139.08 (18.62)	143.00 (17.83) *	.042	.175
	Control	133.75 (11.94)	134.67 (12.15)		

R, right leg; L, left leg; *P*, p-value; Part η^2, eta partial squared. *Training-by-group significant interaction for the composite score ($p < 0.05$).

monopodalic, bipodalic and alternate) with consecutive quick jumps. It is conceivable that such combinations of steps and jumps (e.g. double under exercise) provided shorter contact time and higher jump height (Makaruk, 2013). In particular, during JR muscle groups of the thighs and crural regions are being stimulated to work with a stretch-shortening cycle (SSC) contraction (Miyaguchi et al., 2014b). The ability to increase contractile performance through a combination of eccentric and concentric contractions underlies the mechanism of the plyometric exercises in which a great power output is produced over a brief period of time. Thus, although no potential physical improvements were assessed in this study (e.g. running speed, jumping height), it can be speculated that 8 weeks of JR training may have led an increase in SSC ability. This would have allowed children to obtain substantial positive effects in turning tasks and speed running (Miyaguchi et al., 2014a) as shown by their performance during HCT. In support of this, previous research has demonstrated that plyometric training can be considered an effective alternative stimulus to improve pre-planned agility (i.e. change of direction speed) outcomes in young adult participants (Miller et al., 2006). Furthermore, other authors demonstrated that jumping rope was effective to improve SSC ability in athletes with a little or no experience in exercises related to plyometrics (Miyaguchi et al., 2014b). Children who participated in the present research had never practiced with those type of SSC exercises before they were enrolled. Thus, it can be also hypothesized that the children's initial unfamiliarity with rope jump conditioning have highlighted a great development in the trainability of their power performance parameters (Michailidis et al., 2013). As regard postural control outcomes, the EG exhibited a greater gain in the composite reach scores for both lower limbs than the CG after 8 weeks of training program. This difference seems to reflect a relationship between continuous vertical jumps and balance ability (Myer et al., 2006). Dynamic balance helps athletes to conserve a more stable center of gravity during deliberate activities or sport-specific movements (Lockie et al., 2013). In particular, during every single jump with turning the rope, the children had to stabilize body segments against landing forces in a very short time to maintain suitable the following motion. For example, in the scissors step and alternate foot step exercises, children performed rope rotations moving legs in the sagittal plane. As a result, a great effort had to be done to maintain the body stable during the combination of upper and lower-body movements during flight, landing and take-off phases. However, YBT-LW refers to a measure of balance with a unilateral stance. A recent study corroborated that postural stability calculated immediately (5-20 s after landing) after a jump landing cannot be related to the postural stability obtained from a single leg stance balance task (Fransz et al., 2014). Nevertheless, it appears that significant increases found for both legs on the composite score of the EG are due mostly to the enhancement in the motor coordination. On the other hand, such increases can be also attributed to an improvement of the neuromuscular control of lower limb muscle groups, linked to the balance capacity (Ozer et al., 2011).

A major limitation of the present study is related to the absence of physical tests assessing sprint or jump performance. Outcomes from these tests would have clearly supported the assumption about the use of JR training to improve SSC ability. However, the inclusion of such comparison was not part of the purpose of this research. A further limitation of the present study is the lacking of a maturation status assessment of all participants to provide actual outcomes from HCT and YBT-LW. Although no differences were observed among height, weight and body mass between EG and CG, somatometrics characteristics may also influences strength and power levels among preadolescent soccer players (Michailidis et al., 2013). Further studies should be encouraged to introduce a measure of biological maturation status (e.g. through non-invasive procedures) to corroborate or not our results.

However, the present research provided novel findings in the field of science applied to soccer. They indicate that jump rope training may have a supporting role for improving motor coordination and balance performance in preadolescent soccer players. The use of alternative exercises, which are atypical of the engaged sport (i.e. jumping rope) may allowed children to improve important capacities such as coordination and balance. For that reason, promoting such exercises within soccer-specific program would be beneficial for motor development during the sampling years. On the other hand, further studies should be conducted to evaluate if the training stimulus induced by JR may be transferred positively to soccer technical skills.

Conclusion

Our findings suggested that incorporating JR protocol at the beginning of training sessions was effective to improve motor coordination and balance in preadolescent soccer players over a period of 8 weeks. Thus, an inclusion of physical activities in the form of jumping rope exercises may be more beneficial rather than practicing only soccer specific motor tasks. Coaches and strength and conditioning professionals should be encouraged in developing their training program with a combination of general physical activities and sport-specific exercises.

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Key points

- Performing jumping rope exercises within a regular soccer program can be an additional method to improve balance and motor coordination.
- The performance improvement in the Harre Circuit Test associated with jump rope training can potentially be attributed to an enhancement of the inter-limb coordination and SSC ability.
- Results from the present study indicate that young soccer players should be encouraged to practice general physical activities together with sport-specific exercise during their training sessions.

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a PhD student in Sport Science afferent to the Department of Biomedical Sciences for Health at the Università degli Studi di Milano
Degree
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Research interests
Team sports conditioning programs, strength and conditioning training, talent identification, research methodology, and performance analysis
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