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Original Article

The effects of 8 weeks of integrative neuromuscular pitch training on strength values and sprint performance in young élite soccer players

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Abstract
Introduction. Youth soccer imposes a series of high-intensity movements that require adequate levels of explosive strength from the earliest categories of competition.The organization of training sessions is a very timely issue in youth soccer because it requires careful analysis of modulating loads and managing the duration of training sessions. For these reasons, the following should be sought: a) effective organizational solutions for training the young player, and b) drills and loads that can meet the time allocated to training sessions. **Purpose.**The purpose of the study is to analyse and understand the effects of integrative neuromuscular pitch training on strength values and sprint performances in the young soccer players. **Materials and methods.**37 young male soccer players (all movement players) from youth national team in the 2020/21 season (14.31 ± 0.64 years, weight: 48.96± 6.72 kg; height: 161.1± 9.2 cm, age training: 8,1 ± 1,2 years) have been randomly divided into Experimental Group, EG (n=17) and Control Group, CG (n=20). The EG completed a total of 16 training sessions directed at neuromuscular training on the pitch: two 30-minute sessions/week over a 8-week period. The CG followed an identical training schedule, but training sessions consisted of soccer-specific drills only. The performances were assessed in the One-Leg Hop test, Side-Hop test, CounterMovement Jump (CMJ),10 metres sprint test and 20 metres sprint test. **Results.**The data analysis returns the highlights significant intergroup results (T0 vs T1): the One-Leg Hop test left limb (p = .05, d = -2,67), the Side test left (p= .0005, d= -6.40) and right limb (p= .0005, d= 5.32), the CMJ test ((p= .0005, d= -6.96), the 10 metres sprint test (p= .001, d= -2.04) and the 20 metres sprint test (p= .001, d= -2.25). **Conclusions.**The integrative neuromuscular pitch training seem to respond effectively to two needs of the young soccer player: the lower limb strength values increase and the sprint performance increase.
Keywords: young soccer players – integrative neuromuscular training – sprint – soccer training

Introduction

Youth soccer encompasses many types of young people who play the sport with different levels of performance (Dugdale et al., 2021; Rowat et al., 2017; Palucci Vieira et al., 2019). Strength and conditioning coaches need to understand how to organize training sessions and how to present the motor load in both recreational young soccer players and regional and èlite young soccer players.

In fact, implementing technical drills requires careful analysis of loads and identification of the most functional and beneficial exercises. This factor becomes relevant in soccer performance because the game requires very high intensity actions performed before, during and after controlling the ball: running with changes of direction, decelerations, accelerations and aerial tackles are continuously performed by young soccer players during an official competition and during training sessions. (Kelly et al., 2022; Keiner et al., 2021).

All of these skills need adequate levels of explosive strength to be performed at maximum intensity.
Thus, even in youth soccer and in youth sport there has been a need to introduce motor tasks with the aim of increasing this motor skill (Myer et al., 2011; McBurnie et al., 2021; Willimas et al., 2021; Ceruso et al., 2019; Raiola & Altavilla, 2020).

The effects of integrative neuromuscular training in youth sports have been extensively investigated in the literature: programs conducted with recreational young soccer players (Panagoulis et al., 2020; Sáez de Villarreal et al., 2015), with young rugby players (Alonso-Aubin et al., 2021), with young tennis players (Wang et al., 2022), and to reduce the risk of injury (Fort-Vanmeerhaeghe et al., 2016; Emery & Meeuwisse, 2010) have been monitored. However, the integrative neuromuscular training in youth sports is a very broad idea that needs to be defined and made applicable in different competitive settings and sports.

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The integrative neuromuscular training is considered a relevant factor in the training of the young athlete, regardless of the discipline they choose to practice (Till et al., 2022; Zwolski et al., 2017; Lloyd et al., 2015; Lloyd & Oliver, 2012): the literature proposes to intervene on strength training in the different age groups with tasks adapted to the maturation of young athletes (Sacot ety al., 2022; Myer et al., 2013; Granacher et al., 2016).
Consider that the same sport has different needs for the different competitive age groups: therefore, the introduction of supplementary exercises must consider the technical and tactical needs of the sport and must consider the total motor load. The integrative neuromuscular training must be effective in increasing performance and must be implemented within the session: the duration of this integrative intervention must be limited and allow all technical exercises to be carried out.

In this regard, the literature has already described the relationship between dose and response for integrative neuromuscular training, highlighting how the duration and volume of training are significant in achieving performance gains (Willimas et al., 2021; Steib et al., 2017).

To date, however, the literature has studied the effects of integrative neuromuscular training involving activities performed outside the soccer pitch, or in the gym, with young soccer players (Zghal et al, 2019; Ramirez-Campillo et al, 2018), with young female volleyball players (Trajković & Bogataj, 2020), with young tennis players (Wang et al., 2022) and with young basketball players (Shi et al., 2022) and with young open skills sport athletes (Faigenbaum et al., 2007). And only in very rare cases to understand the effects on injury prevention on young athletes (Olsen et al., 2005; Emery & Meeuwisse, 2010).

Therefore, an open problem remains the analysis of the effects of integrative neuromuscular training exercises involving activities performed in the soccer pitch, which are inserted within the session without interruptions that may affect the training effects. The integrative neuromuscular training conducted on the football pitch allows the team to be organised into two groups that train on different and complementary factors at the same time, reducing time losses. The aim of this study is to analyse and understand the effects of integrative neuromuscular pitch training on strength values and sprint performances in the young èlite soccer players**.**

Materials and methods

Study participants

37 young male soccer players (all movement players) from youth national team (season 2020/2021) participated in the study (average age:14.31 ± 0.64 years, weight: 48.96± 6.72 kg; height: 161.1± 9.2 cm, age training: 8,1 ± 1,2 years). The sample was randomly divided into an Experimental Group (EG, n = 17) and a Control Group (CG, n = 20). The 82.2% of the sample stated that they preferred the right limb and 17.8% the left limb, for kicking.

The sample included all the players that did not report any injuries at the study time, and all the players that were training and playing in matches in the last 6 weeks. One young soccer player did not complete the assessments and was excluded from the statistical analysis. The study was approved by the club's manager, by FIGC (Federazione Italiana Giuoco Calcio) regional ethics committee and was performed according to the principles expressed in the Declaration of Helsinki. The written informed consent was obtained from the parents, while the young soccer players have signed the informed assents.

Study organization

The study was conducted in the winter break of the Under 15 national championship.
The assessments were conducted in the last competitive micro-cycle before the suspension of official matches and in the first micro-cycle when the competitive phase was resumed.
The One-Leg Hop test, the Side Hop test, the CMJ were used to assess the lower limb strength (Mirković et al., 2022; Reid et al.,, 2008); the 10 metres and 20 metres sprint test were used to assess the speed performances.
The One-Leg Hop test and the Side test were conducted directly on the soccer pitch according to protocols already used in the literature (Rodríguez-Rosell et al., 2017; Mirković et al., 2022; Reid et al.,, 2008; Markovic et al., 2004); the CMJ was carried out by means of a conductance platform (Globus, Italy) and the sprint tests by means of photocells (Globus, Italy).

Procedures

The EG completed 2 of 30-minute sessions per week oriented into neuromuscular training (16 sessions in 8 weeks). The two weekly training sessions proposed to the EG were structured differentially (see <ins>Tables 1</ins> and <ins>2</ins> for details).

The scheduling of the exercises considered the demands of the soccer game, namely explosive strength and the ability to decelerate and stabilise.

The training session consisted in 15 minutes of warm-up (aerobic running, dynamic stretching and speed exercises), 30 minutes of integrative neuromuscular training and 45 minutes of soccer-specific drills.
In the other 2 sessions the EG performed only soccer specific drills (90 minutes).

Table 1. Exercises of session 1

Exercise	Task	Sets x repetitions	Recovery time
1. Strength and hold	High skipping with single leg halt every 5 skips.	6 x 5 x limb	20 sec
2. Strength and hold	4 diagonal single-legged bounds, maintaining equilibrium before the last bound for 3 sec.	4 x 6	30 sec
3. Strength and hold	6 forward bounds, maintaining equilibrium before the last bound for 3 sec.	3 x 4 x limb	30 sec
4. Balance and strength	Rebound on single leg on inflatable disk.	4 x 10	20 sec
5. Strength and hold	2 Kg medicine ball chest passes whilst balancing with one-leg	4 x 6 x limb	45 sec
6. Balance and strength	2 Kg medicine ball passes with torsion whilst standing on one leg.	4 x 6 (twice per limb)	45 sec

Table 2. Exercises of session 2.

Exercise	Task	Sets x repetitions	Recovery time
1.Balance and stability	Lateral raises (2 Kg dumb-bells) whilst standing on one leg	3 x 6 x limb	30 sec.
2. Strength and hold	Jump on two inflatable Skimmy cushions (Sixtus, Italy) for 15 seconds.	2 x 4	30 sec.
3. Strength and hold	4 one-legged successive jumps on the ground, maintaining landing position for at least 3 sec.	4 x 4 x limb	30 sec.
4. Strength and hold	Step-up jump on a Bosu balance trainer.	4 x 5 x limb	30 sec.
5. Balance and strength	One-leg jump and 90 degree rotation, and landing on one-leg for at least 3 sec	3 x 6 x limb	30 sec.
6. Balance and stability	Hold on one leg for 10 sec, while the upper limbs "*draw*" a box	3 x 4 x limb	30 sec.

The CG followed a plan that consisted only in soccer-specific drills; 4 sessions of 90-minutes per week were performed in total of 32 sessions (i.e. 8 weeks).
The experimental design is summarized in table 3.

Table 3. The experimental design in the every week microcycle.

	Day 1	Day 2	Day 3	Day 4
EG	Neuromuscular training (session 1) + soccer drills	Soccer drills	Neuromuscular training (session 2) + soccer drills	Soccer drills
CG	Soccer drills	Soccer drills	Soccer drills	Soccer drills

Statistical analysis

The descriptive statistics (mean, standard deviation, confidence interval) were determined for all test data. To verify the intergroup differences (EG vs CG) in the pre and post test (T0 vs T1) the T-test for independent data was used, with significance fixed at $p < 0.05$; for the differences between the averages that were significant, Cohen's d was used to check the effect size index. As for the effect size index (Effect Size), after calculating the δ index it is possible to convert it into Effect Size: ≤ 0.20 small; 0.50 average; ≥ 0.80 large [50]. The statistical package SPSS 15.0 for windows (SPSS Institute, Chicago, IL) was used to analyse all data.

Results

No significant between-group differences were shown at baseline.
The data analysis returns the highlights significant intergroup results (T0 vs T1):
- the One-Leg Hop test left limb: $t(36) = -2.673$, $p = .01$, $d = -2{,}67$,;
- the Side test right limb: $t(36) = 5.325$, $p = .0005$, $d = 5.32$,;
- the Side test left limb: $t(36) = - 6.403$ $p = .0005$, $d = 6.40$;
- the CMJ test: $t(36) = -6.968$, $p = .0005$, $d = -6.96$;
- the 10 metres sprint test: $t(36) = -2.046$, $p = .001$, $d = -2.04$;
- the 20 metres sprint test: $t(36) = 2.255$, p= .001, d=2.25.

In the table 4 are summarized all data.

Table 4. The results. Legend: CG: Control Group; EG: Experimental Group; CMJ: Countermovement Jump; ES: Effect Size

Variable	Group	m±ds	Gl	T	p value	ES
Hop test right limb (T0) cm	CG EG	146.71±15.7 143.71±21.84	36	.494	.625	
Hop test right limb (T1) cm	CG EG	150.71±12.76 153.88±19.76	36	-1.633	.111	
Hop test left limb (T0) cm	CG EG	151.91±21.14 148.78±26,82	36	.790	.435	
Hop test left limb (T1) cm	CG EG	146.19±17,67 164.47±20.75	36	-2.673	.01	2.67 (large)
Side test right limb (T0) cm	CG EG	116.6±12.11 118.41±18.12	36	-917	.365	
Side test right limb (T1) cm	CG EG	119.9±11.45 134.21±9.8	36	-5.325	.000	5.32 (large)
Side test left limb (T0) cm	CG EG	124.6±11.7 125.8±10.3	36	-1.473	.149	
Side test left limb (T1) cm	CG EG	129.81±12.61 138.9±7.12	36	-6.403	.000	-6.40 (large)
CMJ (T0) cm	CG EG	28.11±4.61 29.88±3.99	36	.538	.594	
CMJ (T1) cm	CG EG	29.11±4.33 36.42±2.64	36	6.968	.000	6.96 (large)
Sprint 10m (T0) sec	CG EG	2.41±0.32 2.43±0.46	36	.990	.329	
Sprint 10m (T1) sec	CG EG	2.38±0.27 2,22±0.12	36	2.046	.00	2.04 (large)
Sprint 20m (T0) sec	CG EG	3.12±0.29 3.09±0.43	36	-.593	.557	
Sprint 20m (T1) sec	CG EG	3.10±0.36 2.92±0.15	36	2.255	.00	2.25 (large)

Discussion

This study aimed to verify the effects of integrative neuromuscular pitch training on strength values and sprint performances in the young èlite soccer players**.** This is the first study that intends to verify the effects of pitch-based neuromuscular training on strength and acceleration values in young soccer players.

Currently, the needs of each sport require that the phase conditioning must be of limited duration and compatible with the other needs of training session: in particular, the sport teams should provide an high numbers of exercises that must respond the technical match profile demands.

Therefore, the type of training to be propose must try to meet at least two needs: a) to determine positive adaptations in the young athlete motor abilities and b) to increase technical skills of the young soccer players. The integrative neuromuscular pitch training plans must be effective and limited within a compatible duration with the technical and tactical needs of young athletes (Rahlf et al., 2020; Negra et al., 2020a) Vice versa, the literature indicates that it may be difficult to implement the sessions and achieve adequate compliance, as was the case with the injury prevention protocols (Rössler et al., 2014).

The Hop tests are a valid tool for analyzing and monitoring the single leg strength (Helme et al., 2021): they, in fact, rather than evaluations with isokinetic dynamometers (Bishop et al., 2021), reproduce the same movements required to the young soccer players by the performance model (Reinhardt et al., 2020).

The post test strength values showed increases in unilateral jumping performance in the One-Leg Hop test (left limb), in the Side test (right and left limb), and in the CMJ test: the 16 training sessions of neuromuscular tasks showed respectively an increase approximately of 14%, 13.5%, 11.2% and 19.4%.

Other studies conducted on under-17 young soccer players using unilateral tasks with conical pulley tools, have led to less increase performances in jumping assessment (Gonzalo-Skoket al., 2019); indeed, other studies with young soccer players have reported very similar risings in performance using strength training with body weight (McKinlay et al., 2018; Bedoya et al., 2015, with free weights (Loturco et al., 2020) or with loaded and unloaded plyometric tasks (Negra et al., 2020b).

The statistically significant strength increase only for the left lower limb, in the One-Leg Hop test can be explained by the preferred limb for kick of this sample of study: the 82.2% of the sample stated they preferred the right limb to kick. It follows that the left limb is the one that is mostly chosen to give support to the body and to manage the landing ground phase in a one-leg position; so it may be the most stressed limb and therefore strongest in handling the weight of the young athlete (Moreno-Azze et al., 2021a & 2021b).

The increase in explosive strength values agrees with the findings of the 10- and 20-metre acceleration tests in the EG and with the findings in the literature (França et al., 2022; Seitz et al., 2014): functional relationships between strength and sprinting abilities can also be evidenced in the young soccer players, especially when the distances are shorter than 30 metres (Fernández-Galván et al., 2022; Rodríguez-Rosell et al., 2017b). The young Under-15 soccer players who underwent integrative neuromuscular pitch training showed an increase in performance in the 10-metre and 20-metre distances of approximately 7.7% and 5.6%, respectively.
The sprint performances are in line with what has been shown in the literature with elite young soccer players (Trecroci et al., 2018; Nobari et al., 2021).

The modest effects of sport -specific training in CG confirm what has been highlighted in the literature where it emerges that integrated training is more effective than technical training alone (Köklü, et al., 2020) and where it is highlighted that the choice of technical drills is decisive in enabling effective adaptations (López-Fernández et al., 2020; Póvoas et al., 2018; Katis et al., 2009; Halouani et al., 2014).

Thus, integrative neuromuscular training appears to be functional for the development of the young footballer: the benefits deriving from technical training based on sport-specific skills can be combined with those deriving from motor skills acquired through motor tasks based on movement control and muscle strength control (Lin et al., 2022). It is for these reasons that the literature recognises with new evidence the need to implement training of young athletes of all sports with this type of motor task (Lin et al., 2022; Sinđić et al., 2021; Duncan et al, 2018): indeed, integrative neuromuscular training has been identified as an advanced and effective method for promoting children's movement competence, fitness, and even athletic performance (Akbar et al., 2022; Lin et al., 2022; Sinđić et al., 2021; Faigenbaum et al., 2011).

Further studies will have to analyse and describe the dose-response relationships of integrative neuromuscular training in order to understand how many sessions per week are required, what volume of training for each age group and for which type of sport should be offered; furthermore, further investigations are required to identify the most effective exercises that can be used on the pitch and with which technical exercises they should be combined to make the training sessions more functional.

Conclusions

The demands of the performance model in youth football must direct the attention of staff to new ways of organising training sessions.
These ways of organising must seek to optimise the time available to train both technical and conditional aspects. The integrative neuromuscular pitch training seem to respond effectively to two needs of the young soccer player: the lower limb strength values increase and the sprint performance increase

Conflict of interest

The authors declare no conflict of interest.

Authors' Contribution: Italo Sannicandro: Study design; Statistical analysis; Manuscript Preparation; Giacomo Cofano: Data collection; D'Onofrio Rosario: Study design
All authors contributed to manuscript and approved the submitted version.

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