ORIGINAL SCIENTIFIC PAPER

Upper-Body Neuromuscular Conditioning Enhances Repeated Sprint Performance in Elite Amputee Soccer: A Controlled 12-Week Intervention Study

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Abstract

Repeated sprint ability (RSA) is a key physical determinant of performance in intermittent sports such as football, reflecting the capacity to perform repeated high-intensity efforts with limited recovery. In amputee soccer, locomotion is characterized by unilateral lower-limb propulsion combined with crutch-assisted upper-body movement, which imposes specific neuromuscular and metabolic demands. Despite the growing popularity of amputee football, limited research has examined targeted conditioning strategies aimed at improving RSA in this population. This study investigated the effects of a 12-week upper-body neuromuscular conditioning program on RSA performance in elite amputee soccer players. Eighteen male players from the Moroccan national team were randomly assigned to an experimental group (n=9) and a control group (n=9). Both groups continued their regular training, while the experimental group performed additional upper-body strength sessions. RSA performance was assessed before and after the intervention using a standardized repeated sprint protocol. Variables included best sprint time (BT), mean sprint time (MT), total sprint time (TT), and fatigue index (FI). Post-intervention results revealed significant improvements in the experimental group compared with the control group for BT ($p=0.010$; $d=1.37$), MT ($p=0.013$; $d=1.33$), and TT ($p=0.012$; $d=1.33$). No significant changes were observed for FI ($p=0.420$). Change score analysis further confirmed greater improvements in the experimental group, particularly for BT. These findings suggest that the addition of targeted upper-body neuromuscular conditioning to regular training may improve RSA performance in amputee soccer players, highlighting the relevance of sport-specific strength training adapted to the unique biomechanical demands of this population.

Keywords: *amputee soccer, repeated sprint ability, neuromuscular training, upper-body strength, sprint performance, adaptive sports*

Introduction

Football is widely recognised as a high-intensity intermittent team sport characterised by repeated bouts of intense activity interspersed with periods of lower-intensity movement. In match play, athletes execute multiple accelerations, decelerations, directional changes, and brief sprints, which are frequently critical for attacking and defensive manoeuvres (Buchheit & Laursen, 2013; Rampinini et al., 2007). Consequently, RSA has become a key performance determinant in modern football and a central component of physical conditioning programmes.

RSA denotes the interplay among neuromuscular power, anaerobic metabolism, and recovery ability, especially the fast resynthesis of phosphocreatine during brief recovery intervals (Bishop et al., 2011; Girard et al., 2011). In elite able-bodied football, multiple studies indicate that players with enhanced repeated sprint ability (RSA) exhibit a stronger capability for executing critical high-intensity actions during matches, such as counterattacks, defensive recovery runs, and offensive transitions (Rampinini et al., 2007). While RSA has undergone significant examination in able-bodied football players, research pertaining to amputee soccer is still comparatively scarce. This lack of evidence is particularly important given the unique locomotor constraints associated with amputee soccer. Amputee soccer is an emerging adapted sport involving athletes with unilateral lower-limb amputation who use elbow crutches for locomotion. This unique locomotor pattern imposes distinct biomechanical and physiological demands compared with able-bodied football. (Miyamoto et al., 2018).

Amputee soccer players must coordinate propulsion using a single lower limb while simultaneously stabilising the body and assisting locomotion through the use of elbow crutches. Consequently, sprinting performance in amputee soccer necessitates not only lower-limb power but also considerable upper-body strength, trunk stability, and neuromuscular coordination (Simim et al., 2018). Prior studies have shown that these biomechanical limitations substantially affect locomotor efficiency and sprint mechanics in amputee athletes.

These biomechanical constraints highlight the potential importance of upper-body neuromuscular capacities for sprint propulsion and repeated high-intensity actions in amputee soccer. Match analyses have underscored the high-intensity intermittent characteristics of amputee soccer. Research examining physiological responses during amputee soccer matches has indicated significant cardiovascular and metabolic demands, with players executing frequent high-intensity movements throughout the competition (Simim et al., 2013, 2018). Recent activity profile analyses have verified that amputee soccer entails various high-intensity locomotor actions, including accelerations, decelerations, and brief sprints, which are crucial for effective performance in both offensive and defensive phases of play (Muracki et al., 2023; Nowak et al., 2022). In amputee soccer, upper-body propulsion, trunk stability, and neuromuscular coordination are essential for effective sprinting and repeated high-intensity actions. However, most available studies remain descriptive and have focused mainly on match demands, locomotor patterns, and physiological responses during competition.

Despite these insights, the majority of existing studies remain descriptive in nature and do not provide evidence on the effectiveness of targeted training interventions in this population. RSA is a critical physical quality in amputee soccer, and upper-body propulsion is central to sprint execution; however, no intervention study has yet examined whether targeted upper-body conditioning can improve RSA performance in this population.

Understanding how structured training interventions influence RSA performance therefore represents an important research priority, given the decisive role of sprint actions in match performance and the unique locomotor constraints of amputee soccer. Identifying effective conditioning strategies is therefore essential to enhance physical preparation and optimize performance in amputee soccer players. Therefore, the aim of the present study was to investigate the effects of a 12-week upper-body neuromuscular conditioning programme on repeated sprint ability performance in elite amputee soccer players from the Moroccan national team. It was hypothesised that the experimental training programme would lead to significant improvements in repeated sprint performance compared with the control condition.

Materials and methods

Study design

A controlled longitudinal pre–post intervention design was employed to examine the effects of a structured upper-body strength training program on repeated sprint ability (RSA) in elite amputee soccer players. The intervention lasted 12 weeks and was conducted during the competitive season while participants maintained their regular club and national team training schedules.

Participants were allocated into an experimental group, which performed additional upper-body resistance training, and a control group, which continued regular soccer-specific training only. Performance assessments were conducted before (Pre) and after (Post) the intervention. The design enabled evaluation of both within-group adaptations over time and between-group differences in response to the training stimulus.

The training program was developed according to established principles of resistance training periodization and progressive overload (Harries et al., 2015; Suchomel et al., 2016, 2018), integrating maximal strength, strength–velocity, and muscular endurance components, which are known to influence sprint and repeated sprint performance (Seitz & Haff, 2016).

Due to the practical nature of the intervention, full blinding of participants and staff was not possible; however, RSA testing procedures were standardized across pre- and post-intervention assessments.

Participants

Eighteen male elite amputee soccer players from the Moroccan national amputee soccer team voluntarily participated in this study. All athletes were actively competing at both national and international levels and were regularly engaged in structured training programs with their respective clubs as well as in national team preparation camps during the study period.

Following baseline testing, participants were randomly allocated to either the experimental group or the control group using a simple random assignment procedure performed by the research team: an experimental group (n=9; age: 23.78±0.91 years; body mass: 59.33±2.71 kg; height: 1.72±0.02 m; body fat: 6.28±0.55%) and a control group (n =9; age: 24.00±0.87 years; body mass: 57.44±2.89 kg; height: 1.68±0.01 m; body fat: 5.74±0.40%).

All participants were unilateral lower-limb amputee outfield players competing under the official rules of amputee soccer. Throughout the intervention period, both groups continued their regular football training programs, which included technical, tactical, and physical conditioning sessions planned by their club and national team coaches. No additional structured upper-body strength training was performed by the control group during the experimental period.

Intervention program

The experimental group completed three additional upper-body resistance training sessions per week for 12 weeks, organized into three progressive training cycles. The program followed a structured periodized model progressing from muscular endurance to maximal strength and strength–velocity emphasis.

The detailed periodization structure of the 12-week intervention, including weekly training objectives and relative intensities (%1RM), is presented in Table 1.

Table 1. Periodized upper-body strength training program across the 12-week intervention

Cycle	Week	Session Focus	Training Modality	Intensity (%1RM)
Cycle 1	1	1RM testing / Circuit training	Muscular endurance	60–65%
	2	Circuit training / Max strength	Strength–power	65–80%
	3	Muscular endurance / Max strength / Speed strength	Strength–power	70–85%
	4	Circuit training / Isometric + bodyweight plyometrics / Speed strength	Power emphasis	~70%
Cycle 2	5	Isometric + plyometrics / Circuit training / Max strength	Strength–power	75–90%
	6	Circuit training / Plyometrics / Speed strength	Power emphasis	~75%
	7	Muscular endurance / Max strength / Speed strength	Strength–power	70–90%
	8	Circuit training / Max strength / Speed strength	Peak strength	75–96%
Cycle 3	9	Isometric + plyometrics / Muscular endurance / Speed strength	Power maintenance	70–75%
	10	Muscular endurance / Plyometrics / Speed strength	Power maintenance	~70%
	11	Plyometrics / Speed strength	Tapering phase	65%
	12	Plyometrics / Speed strength	Tapering phase	65–70%

Training targeted upper-body musculature involved in propulsion and trunk stabilization during crutch-assisted sprinting. The specificity of amputee soccer, characterized by asymmetrical load distribution and upper-limb propulsion, requires targeted neuromuscular conditioning strategies (Bragaru et al., 2011, 2012; Nolan, 2008). Core stabilization exercises were incorporated due to their role in force transmission and locomotor efficiency (Prieske et al., 2017). The integration of maximal strength and strength–velocity components were based on evidence linking neuromuscular development to sprint and repeated sprint performance (Loturco et al., 2016; Suchomel et al., 2016).

Exercises were organized using a three-station model, with players grouped according to similar 1RM levels to facilitate load progression. The distribution of exercises and training organization within each session are summarized in Table 2.

Table 2. Exercise distribution and three-station training structure

Station	Exercises	Main target muscles	Sets	Specific notes
Station 1	Bench press – Seated row – Plank	Pectorals, Triceps, Latissimus dorsi, Core	3 sets/exercise	Core held 45 s
Station 2	Preacher curl – Skull crusher – Dips	Biceps, Triceps, Deltoids	3 sets/exercise	Controlled execution
Station 3	Machine shoulder press – Wrist flexion/extension – Side plank	Deltoids, Forearm flexors/ extensors, Core	3 sets/exercise	Core held 45 s

Maximal strength (1RM) was assessed prior to the intervention using adapted resistance machines targeting muscles primarily involved in crutch-assisted sprinting. Training loads were individualized based on 1RM values to ensure progressive overload throughout the intervention period.

All sessions were supervised by qualified personnel, and attendance was monitored throughout the intervention period. Participants in the experimental group completed the full training program, corresponding to 36 sessions (3 sessions per week over 12 weeks), indicating high adherence to the intervention. The control group continued regular soccer-specific training and did not perform additional structured upper-body resistance sessions during the study period.

Repeated sprint ability testing

Repeated sprint ability (RSA) was assessed using the Cazorla repeated sprint test with change of direction, a field-based protocol commonly used to evaluate high-intensity intermittent performance in football players. RSA testing provides an ecologically valid measure of an athlete's capacity to perform repeated maximal sprint efforts with limited recovery, which represents a key determinant of performance in intermittent sports (Bishop et al., 2011; Girard et al., 2011).

The protocol consisted of twelve maximal 20 m shuttle sprints involving multiple changes of direction. Participants started from a standing position approximately 0.5 m behind the starting photocell (time zero) and performed a 20 m sprint including successive directional changes after 4.30 m, 3.20 m, 5.00 m, and 3.20 m, before crossing the finish line where a second photocell was positioned. Sprint times were recorded to the nearest 0.01 s using a dual-beam photocell timing system, ensuring high measurement precision (Haugen & Buchheit, 2016).

Each sprint was separated by 40 s of passive recovery, during which participants walked back to the starting line. Standardized verbal cues were provided during the recovery interval to ensure consistent timing and readiness for the next repetition. Specifically, verbal feedback was given at 20, 30, and 35 s, followed by the command "ready" at approximately the 37th second and "go" at the 40th second to initiate the subsequent sprint. This procedure was repeated until all twelve sprint repetitions were completed, following the protocol originally described by Cazorla (2006).

From the recorded sprint times, several indices were calculated to characterize repeated sprint performance: the best sprint time (BT), defined as the fastest sprint achieved during the test; the mean sprint time (MT), calculated as the average sprint time across all repetitions; the total sprint time (TT), corresponding to the cumulative time of the twelve sprints; and the fatigue index (FI), calculated using the percentage decrement method to quantify the decline in performance across successive sprints (Girard et al., 2011; Spencer et al., 2005).

Prior to testing, all participants performed a standardized dynamic warm-up consisting of mobility exercises, progressive accelerations, and submaximal sprint efforts to ensure optimal neuromuscular readiness. All tests were conducted on the same playing surface under similar environmental conditions, and strong verbal encouragement was provided to ensure maximal effort during each sprint repetition.

Statistics

Statistical analyses were conducted using IBM SPSS Statistics software. Data are presented as mean ± standard deviation (SD). The normality of the distribution was assessed using the Shapiro–Wilk test.

Independent samples t-tests were used to compare group differences at pre-test and post-test. When homogeneity of variances was not assumed, Welch's correction was applied.

To further evaluate the effectiveness of the intervention, change scores (Δ = post-test minus pre-test) were calculated for all repeated sprint ability variables (BT, MT, TT, and FI). Independent samples t-tests were then used to compare the magnitude of change between the experimental and control groups.

Effect sizes were calculated using Cohen's d and interpreted according to established guidelines (Cohen, 1992). Best sprint time (BT), mean sprint time (MT), and total sprint time (TT) were considered primary outcomes, whereas fatigue index (FI) was treated as a secondary exploratory variable due to its known limitations in reliability.

Results

Verification of statistical assumptions

Prior to conducting inferential statistical analyses, the distribution of the study variables was examined in order to verify the assumptions required for parametric testing. Normality of the data was assessed using the Shapiro–Wilk test, which is recommended for small sample sizes. The results of the normality analysis are presented in Table 3.

Table 3. Results of the Shapiro–Wilk normality test

Variables	Statistic	df	Significance
BT (s)	0.935	18	0.240
MT (s)	0.942	18	0.315
TT (s)	0.944	18	0.337
FI (s)	0.905	18	0.070

Note. BT: Best sprint time; MT: Mean sprint time; TT: Total sprint time; FI: Fatigue index.

Shapiro–Wilk testing indicated no significant deviation from normality for BT, MT, TT, or FI (all $p>0.05$). Therefore, the assumption of normality was satisfied, allowing the use of parametric statistical tests, allowing the use of parametric statistical tests, specifically the independent samples t-test, for the subsequent analyses.

Baseline comparability between groups

To verify the initial equivalence between the experimental and control groups prior to the intervention, independent samples t-tests were conducted on the repeated sprint ability (RSA) performance variables during the pre-test phase. The results of these comparisons are presented in Table 4.

Table 4. Comparison of RSA performance variables between groups at pre-test

Variables	Group	Mean ± SD	t	df	p-value
BT	Experimental	5.71±0.37	1.644	16	0.120
	Control	6.01±0.39			
MT	Experimental	5.99±0.44	1.647	16	0.119
	Control	6.33±0.42			
TT	Experimental	71.93±5.22	1.641	16	0.120
	Control	75.91±5.08			
FI	Experimental	4.80±2.39	0.526	16	0.606
	Control	5.35±1.96			

Note. BT: Best sprint time; MT: Mean sprint time; TT: Total sprint time; FI: Fatigue index.

The comparison of repeated sprint ability (RSA) performance variables between the experimental and control groups during the pre-test phase revealed no statistically significant differences for any of the variables analyzed. Specifically, the results showed non-significant differences for best sprint time (BT) ($t=1.644$, $p=0.120$), mean sprint time (MT) ($t=1.647$, $p=0.119$), total sprint time (TT) ($t=1.641$, $p=0.120$), and fatigue index (FI) ($t=0.526$, $p=0.606$).

These findings indicate that both groups presented comparable levels of repeated sprint ability prior to the implementation of the training intervention. Therefore, the absence of significant differences confirms the initial homogeneity of the two groups and ensures that any changes observed in the post-test can be attributed to the experimental training program.

Effects of the training intervention on RSA performance

To evaluate the effect of the training intervention on repeated sprint ability (RSA) performance, independent samples t-tests were conducted to compare the post-test results between the experimental group and the control group. The comparison focused on the main RSA performance variables, including best sprint time (BT), mean sprint time (MT), total sprint time (TT), and fatigue index (FI). The results of these post-test comparisons are presented in Table 5.

Table 5. Comparison of RSA performance variables between groups at post-test

Variables	Group	Mean ± SD	/t/	df	P-value	Cohen's d effect size
BT	Experimental	5.46±0.44	2.911	16	0.010	1.37
	Control	6.05±0.41				
MT	Experimental	5.61±0.44	2.813	16	0.013	1.33
	Control	6.18±0.42				
TT	Experimental	67.29±5.25	2.813	16	0.012	1.33
	Control	74.11±5.04				
FI	Experimental	2.70±1.62	0.829	16	0.420	0.39
	Control	2.16±1.10				

Note. BT: Best sprint time; MT: Mean sprint time; TT: Total sprint time; FI: Fatigue index.

The comparison of repeated sprint ability (RSA) performance variables between the experimental and control groups at post-test revealed significant differences for several variables. Specifically, statistically significant improvements were observed in the experimental group for best sprint time (BT) (t=2.911, p=0.010), mean sprint time (MT) (t=2.813, p=0.013), and total sprint time (TT) (t=2.813, p=0.012). These results indicate that the experimental group achieved better sprint performance compared with the control group following the training intervention. Furthermore, the magnitude of these differences was evaluated using Cohen's d effect size. The results showed effect sizes of d=1.37 for BT, d=1.33 for MT, and d=1.33 for TT, indicating a substantial practical impact of the training program on RSA performance. In contrast, no statistically significant difference was observed between the two groups for the fatigue index (FI) (t=0.829, p=0.420). The effect size for this variable was small (d=0.39), suggesting that the intervention had a limited effect on fatigue-related performance during the RSA test.

Table 6. Between-group comparison of change scores (Δ = post−pre) for RSA performance variables

Variables	Group	Δ (Mean ± SD)	/t/	df	p-value	Cohen's d
ΔBT	Experimental	-0.25±0.36	2.22	11.33	0.047	1.05
	Control	0.04±0.17				
ΔMT	Experimental	-0.39±0.30	2.07	11.85	0.061	0.97
	Control	-0.15±0.15				
ΔTT	Experimental	-4.64±3.64	2.08	11.94	0.060	0.98
	Control	-1.80±1.87				
ΔFI	Experimental	-2.10±2.73	0.81	15.91	0.429	0.38
	Control	-3.18±2.94				

A statistically significant between-group difference was observed for ΔBT (t(11.33)=2.22, p=0.047), indicating greater improvement in maximal sprint performance in the experimental group. Although ΔMT and ΔTT did not reach statistical significance (p=0.061 and p=0.060, respectively), both variables showed large effect sizes (d=0.97 and d=0.98), suggesting potentially meaningful practical improvements. No significant between-group difference was observed for ΔFI (p=0.429; d=0.38).

Overall, these findings suggest that the intervention was associated with improvements in BT, while producing potentially meaningful, though not statistically significant, changes in MT and TT; however, these results should be interpreted with caution due to the small sample size and the additional training stimulus received by the experimental group.

Discussion

The main finding of this study was that the addition of a 12-week upper-body neuromuscular conditioning program to regular training was associated with improvements in BT, and with potentially meaningful improvements in MT and

TT, in elite amputee soccer players. In contrast, no clear effect was observed for FI, which should be interpreted cautiously given its known limitations in reliability and sensitivity.

RSA performance in amputee soccer

RSA is a key determinant of performance in intermittent sports such as football, as it reflects the ability to perform repeated high-intensity efforts with limited recovery. In amputee soccer, match analyses have shown that players frequently execute short sprints to reach the ball, reposition defensively, or initiate attacking actions (Muracki et al., 2023; Nowak, 2020; Simim et al., 2013). The improvements observed in BT, MT, and TT in the present study therefore suggest that the intervention was associated with an enhanced capacity to produce repeated high-intensity efforts under sport-specific conditions. Given the intermittent nature of amputee soccer, such improvements may translate into more effective participation in decisive match situations, including offensive transitions and defensive recovery actions (Simim et al., 2017). These findings also highlight the functional relevance of RSA in this population, where performance is strongly influenced by the ability to repeatedly accelerate and decelerate while maintaining balance and coordination during crutch-assisted locomotion. Consequently, enhancing RSA through targeted conditioning may represent an important component of physical preparation in amputee soccer players (Bragaru et al., 2011).

Biomechanical and locomotor constraints in amputee soccer

Amputee soccer players move around with crutches and use only one healthy lower limb to push themselves (Baum et al., 2019; Beck et al., 2022; Tatar et al., 2018). This locomotor pattern differs substantially from that observed in able-bodied football (Baum et al., 2013; Bednarczuk et al., 2025). Miyamoto et al., (2019) showed that the speed of an amputee soccer player's sprint is closely linked to the way they move during a sprint and how well they can produce force while walking with crutches. Their findings indicate that propulsion mechanics differ substantially from those observed in able-bodied athletes, requiring greater coordination between the intact limb and upper-body musculature. Likewise, performance analyses of amputee soccer players indicate that successful performance is significantly contingent upon the capacity to accelerate swiftly while preserving balance and stability (Esatbeyoglu et al., 2022, 2024). Sprinting in amputee soccer likely imposes greater neuromuscular demands due to the simultaneous requirements of propulsion, balance, and crutch coordination. Moreover, research on the physical characteristics of amputee athletes demonstrates that upper-body endurance and trunk stability are essential for locomotor efficiency. For example, a study on the endurance of amputee players' scapular and core muscles found that the trunk muscles play a big role in keeping the body stable during high-intensity movement (Gunaydin, 2021). These findings suggest that the observed improvements in sprint performance may be partially explained by enhanced neuromuscular coordination between the upper limbs, trunk, and intact lower limb.

Physiological and neuromuscular mechanisms underlying improvements in RSA

The improvements observed in BT, MT, and TT may be explained by specific neuromuscular adaptations induced by the upper-body conditioning program. In amputee soccer, repeated sprint performance is not solely dependent on lower-limb power but also relies heavily on upper-body force production, trunk stability, and inter-limb coordination during crutch-assisted locomotion (Miyamoto et al., 2019; Simim et al., 2025; Tatar et al., 2018). Upper-body neuromuscular training may enhance motor unit recruitment, coordination, and force transmission between the upper limbs, trunk, and the intact lower limb (Gunaydin, 2021). These adaptations are particularly relevant in amputee athletes, where propulsion and balance must be controlled simultaneously. Improved upper-body strength and trunk stability can contribute to more efficient force application during sprinting, thereby enhancing sprint acceleration and overall repeated sprint performance. Additionally, previous research has shown that high-intensity intermittent efforts in amputee soccer impose significant cardiovascular and metabolic demands (Maehana et al., 2018; Simim et al., 2013, 2018, 2025). Although the present intervention was not specifically designed to target metabolic conditioning, improvements in neuromuscular efficiency may indirectly contribute to better energy utilization during repeated efforts. However, the absence of a significant effect on FI suggests that the intervention primarily improved sprint output rather than fatigue resistance. This finding is consistent with the nature of the training stimulus, which emphasized neuromuscular and strength development rather than metabolic adaptations. To further improve fatigue resistance, additional training components focusing on anaerobic endurance and metabolic conditioning may be required (Nowak et al., 2021).

Comparison with previous studies in amputee soccer

The present findings are consistent with previous research highlighting the importance of sprint performance in amputee soccer. Studies have shown that sprint speed and locomotor efficiency are key determinants of performance, particularly due to the specific constraints of crutch-assisted locomotion (Migliore et al., 2021; Miyamoto et al., 2019). Match analyses further indicate that amputee soccer is characterized by frequent high-intensity actions, including accelerations, decelerations, and short sprints, which are essential for both offensive and defensive phases of play (Simim et al., 2017, 2018, 2025). In this context, the improvements observed in repeated sprint variables (BT, MT, and TT) are consistent with the physical demands reported in the literature and reinforce the relevance of RSA as a key physical attribute in this population. Furthermore, previous studies have reported high perceived exertion during amputee soccer matches, reflecting the substantial physiological demands imposed by repeated high-intensity efforts (Aküzüm et al., 2023; Yakal et al., 2023). These findings support the need for targeted conditioning strategies aimed at improving both sprint performance and the ability to tolerate repeated high-intensity efforts.

Practical applications

From a practical standpoint, the findings of this study provide important insights for coaches and practitioners working with amputee soccer players. The observed improvements in RSA performance suggest that integrating structured upper-body neuromuscular conditioning into training programs may enhance players' ability to perform repeated high-intensity efforts. In addition, comprehensive conditioning programs may benefit from incorporating exercises targeting upper-body strength, trunk stability, and the intact lower limb. Furthermore, monitoring training load through a combination of objective performance indicators and subjective measures such as perceived exertion may help optimize training prescription and reduce the risk of excessive fatigue or overtraining.

Study limitations and future research directions

Despite these findings, several limitations should be considered. First, the relatively small sample size may limit the generalizability of the results. Second, the duration of the intervention may have been insufficient to induce measurable changes in fatigue resistance. Future studies should investigate longer training interventions and explore the combined effects of repeated sprint training and metabolic conditioning on RSA performance. Additionally, integrating biomechanical analysis and physiological monitoring techniques could provide deeper insights into the mechanisms underlying performance improvements in amputee soccer players.

Conclusions

In conclusion, the addition of a 12-week upper-body neuromuscular conditioning program to regular training was associated with improvements in best sprint time, and with potentially meaningful improvements in mean and total sprint time, in elite amputee soccer players. No clear improvement was observed for fatigue index. These findings support the practical integration of upper-body conditioning into training programs for amputee soccer players.

Acknowledgments
There are no acknowledgments.

Conflicts of Interest
The authors declare no conflict of interest.

Received: 23 March 2026 | **Accepted:** 20 Aprile 2026 | **Published:** 01 June 2026

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