International Journal of Strength and Conditioning

Curovic, I., Grecic, D., Rhodes, D., Alexander, J., & Harper, D. J. (2025). The Importance of Upper Body Strength Testing and Training For Performance of High-Intensity Actions in Professional Soccer Players: A Survey Exploring Perceptions and Current Practices of Soccer Strength and Conditioning Coaches. International Journal of Strength and Conditioning
https://doi.org/10.47206/ijsc.v5i1.405

The Importance of Upper Body Strength Testing and Training For Performance of High-Intensity Actions in Professional Soccer Players: A Survey Exploring Perceptions and Current Practices of Soccer Strength and Conditioning Coaches

Ivan Curovic[1], David Grecic[2], David Rhodes[3], Jill Alexander[1] and Damian J. Harper[1]

[1]Institute of Coaching and Performance, School of Health, Social Work and Sport, University of Central Lancashire, Preston, UK, [2]Centre for Applied Sport, Physical Activity and Performance, University of Central Lancashire, Preston, UK, [3]Human Performance Department, D.C. United Football Club, Washington, USA

ABSTRACT

This study aimed to investigate the perception of soccer strength and conditioning (S&C) coaches on the importance of upper body (UB) strength training for the performance of high-intensity actions (HIA) (i.e., sprinting, repeated sprint ability, change of direction, and jumping) in professional soccer players, and to identify current practices with regards to UB strength testing and training methodologies within this sport. Eighty-six S&C coaches working with professional soccer players volunteered to complete the survey. Twenty-two fixed responses and three open-ended questions were grouped into three sections: (a) demographic information, (b) perspectives on the importance of UB strength and UB strength training for HIA, and (c) current practices of UB strength training in soccer. Frequency analysis was used to assess fixed response questions, and thematic analysis established clear and recognisable themes for open-ended questions. Relative to "not important" options, UB strength was perceived as important for all HIA, especially for jumping (89%) and acceleration (87%). Coaches strongly supported the idea that UB strength plays a role in enhancing HIA, with particular influence on jumping (100%), acceleration (97%) and COD (93%). This positive influence is believed to be realised via improved force transmissions (97%) and neural drive (94%). Notably, however, surveyed coaches overwhelmingly use moderate resistance in their sessions (100%) without substantial emphasis on high-velocity contractions (64%). In conclusion, S&C practitioners value UB strength training for enhancing the performance of HIA in professional soccer players. Further research is needed to explore this link and provide clearer guidance on the implementation of UB strength training in professional soccer.

Keywords: sprinting, repeated sprint ability, acceleration, change of direction

INTRODUCTION

Soccer is a sport in which high-intensity actions (HIA) (such as sprinting, change of direction (COD) and jumping) are crucial for performance [1–5]. With tactical evolutions of the game and more matches within the competitive season, understanding how to enhance and maintain the performance of HIA is of critical importance for future soccer training practices [6]. Although primarily performed by lower body (LB) muscles, these HIA may well be enhanced by strong upper body (UB) muscles [7–9] via improved force transmissions [10–13] and augmentation of forces applied to the ground for acceleration and deceleration [14–16]. Furthermore, UB strength training placed strategically after intense LB sessions could aid in the recovery of leg muscle fibres [17] and LB force-generating capacity [18]. As a result, a player may be able to preserve the ability to produce high forces in shorter time frames (i.e., impulse) [19, 20], translating to improved HIA and soccer performance that result in successful match performance outcomes [21].

While UB strength is advantageous in close-contact situations during soccer matches [22, 23], its influence on HIA remains less clear. This is likely because HIA relies primarily on leg strength for force generation [24–26]. However, Young et al. [7] reported a faster 30-m "flying" sprint for Australian Rules Football players who display greater maximum bench press strength. Moreover, bench press strength has been reported to be significantly associated with improved repeated sprint ability (RSA) [8, 27, 28], although no such investigations have been conducted with soccer players. Trunk extensor muscles have also been assessed as important for sprint acceleration (<20 m distances) [29] and maximal jumping [30, 31] via extended time to generate force gained by arm swings [32]. Lastly, greater maximal isometric strength of all trunk muscles has been reported to be associated with better COD performance [33], likely by helping propel the body to the desired direction after fast transitions from eccentric to concentric phases in quick decelerations, turns and re-accelerations [20, 31, 34].

Current evidence suggests that even highly trained soccer players could gain notable UB strength and power improvements with as little as one UB resistance training session per week [35]. Indeed, the UB strength of soccer players [36, 37] is arguably behind other athletes competing in different codes of football sports [38–40], probably due to the programming of UB exercises falling outside of optimal zones for strength and power development [41] because most actions on a soccer pitch prioritise LB movements [3] that do not require such high collision rates. Therefore, strategically targeting the UB region could appear as a "window of opportunity" for enhanced neuromuscular capacity reflected in maximal power production [42], suggesting that the least developed muscle groups could yield the greatest exercise adaptations, enabling performance enhancements for this individual [42]. There is also evidence to suggest that a vertical strength transfer could be obtained based on strength training in different body regions via neurophysiological mechanisms [17]. Thus, UB exercise sessions might lead to enhanced HIA on account of an improved rate of force development (RFD) and impulse generation for the lower extremities [43–45].

Suarez-Arrones et al. [46] examined the effect of two added eccentric-overload training sessions per week during the competitive season for elite soccer players where one of the sessions targeted UB and core (Day 1), and the other one targeted LB (Day 2), resulting in substantial improvement with sprint performances (i.e., 10, 30 and 40 m) after the intervention. Similarly, a study by Christou et al. [47] demonstrated that the addition of two whole-body strength training sessions per week to soccer-specific regimes increased maximal strength of both UB and LB, as well as vertical jump height and 30-m sprinting speed in adolescent football players after a 16-week programme. Therefore, it is evident that when UB strength is trained alongside LB strength, soccer players' fitness qualities and HIA can be improved, which could significantly impact soccer performance [1–3, 48]. Unfortunately, the importance of UB strength training for HIA performance in soccer players is not well understood, nor are the current UB strength training prescriptions within soccer S&C strategies. Previous surveys exploring contemporary S&C practices have not distinguished between UB and whole-body exercise programming [49–51], although practitioners have expressed the need to programme more UB ballistic exercises [49]. Furthermore, a systematic review by Asimakidis et al. [52] showed that UB strength alone, evaluated exclusively via bench press, is rarely tested in professional soccer. Therefore, this study aimed to investigate the perception of soccer S&C coaches on the importance of UB strength and UB strength training for the performance of HIA and to identify current practices about UB strength testing and training prescriptions for professional soccer players. It was hoped that this information would help to inform future research directions and applied practices around the exploration of UB strength training for its potential contribution to the improvement and recovery of HIA performance for professional soccer players.

METHODS

Experimental approach to the problem

A cross-sectional explorative study was used to investigate perceptions of soccer S&C coaches about the importance of UB strength and UB strength training for the performance of HIA and to identify current practices about UB strength testing and training prescriptions for professional soccer players. A survey was developed using online software (Qualtrics, Provo, USA) to collect answers anonymously in English language. Respondents were recruited using social media platforms (e.g., “X”, Instagram, LinkedIn, Facebook) and via authors’ direct networks. Before distributing the survey, four practitioners reviewed it for apparent validity, providing feedback and suggesting changes before it was ethically approved and circulated. The survey was available online for 10 weeks, from November 23rd, 2023, to February 1st 2024. All responses were anonymous, and the survey was divided into three sections: 1) demographic information, 2) perspectives on the importance of UB strength and UB strength training for HIA in soccer and 3) current applications of UB strength training in soccer. Only the exercises that exclusively involved UB musculature were to be considered with the avoidance of exercises which activate both body regions (e.g., weightlifting derivatives). This was clarified to participants in a “questionnaire specifics” section before participants commenced the main survey sections. Furthermore, HIA was broken down into individual qualities within the questions (i.e., acceleration, maximal velocity, deceleration, COD, and jumping) with the addition of repeated sprint ability (RSA) due to its high relevance for this sport [53] and reported positive links to greater UB strength [8]. This was undertaken to emphasise the distinctive contributions made by UB strength to different types of HIA. A series of multiple-choice (6), Likert scale (8), rank order (1) and open-ended (3) questions were asked, equaling a total of 25 questions. Multiple-choice questions served to assess current applications of UB strength training in soccer, open-ended questions provided the space to elaborate with greater detail on the use and importance of UB exercises for HIA performances, while scale-based and rank order questions revealed coaches’ perceptions of UB strength importance for performance of HIA. This methodological approach to question design has been shown to successfully provide a range of data for analysis and sharing [54], which is deemed essential for the aims of this study.

Participants

Inclusion criteria required coaches to be at least 18 years old and to have working experience in S&C provision with professional male or female soccer players. All respondents gave informed consent at the start of the survey, and those who did not were unable to continue. Participants were asked to provide their demographic information and league in which they worked (via open question response) as well as the gender they coached (via closed question response with options “male” or “female”). In addition, they were required to state their experience of work with professional players (i.e., years, months) and S&C qualification (i.e., National Strength and Conditioning Association (NSCA), United Kingdom Strength and Conditioning Association (UKSCA), Australian Strength and Conditioning Association (ASCA), Collegiate Strength and Conditioning Association (CSCA), or “other”).

Procedures

Each participant provided informed consent to commence the anonymous online survey, and only those who did so were included in the analyses. The survey started with an introduction outlining its purpose, objectives, expected time commitment, and assurance of confidentiality (Supplementary material 1). Ethical approval for the study was granted by the University of Central Lancashire ethics committee (REF: HEALTH 0330 Phase_3) in line with the principles of the Helsinki Declaration (2013). Coaches were notified that they could receive a copy of the results upon request.

Data analysis

The current cross-sectional descriptive study presented the survey data in a descriptive format. In line with previous survey studies [49, 55, 56], fixed responses were presented as absolute values and as a percentage of the total responses, owing to fluctuations in the number of responses to specific questions [57]. For open-ended questions, the lead author categorised the responses and comments into themes [58], following similar approaches used by previous studies investigating perceptions of S&C coaches [49, 55]. This involved familiarisation with the data, coding of the relevant phrases and keywords leading to the recurring themes [59], defining and refining these themes, and interpreting their significance within the context of the research question [60]. This inductive approach allowed for the exploration of the coaches' perspectives and experiences related to the study aims. Likert-scale responses were reported following scale response anchors provided by Vagias [61]. These responses were categorised as either "important" ("very important" + "moderately important") or "not important" ("not important + "low importance") for perceptions, and "agree" ("strongly agree" + "agree") or "disagree" ("strongly disagree" + "disagree") for evaluations, thereby excluding "neutral" and "neither agree nor disagree" response from analysis. To avoid potential bias or inaccurate data through forced question responses, participants did not have to respond to every question within the survey [62]. Therefore, all responses were independently analysed, and percentages were reported relative to each question.

RESULTS

Background information

A total of 86 S&C coaches (65 males, 6 females, 15 undisclosed) completed the survey, out of which 40 responded to all questions. Coaches worked with male (84%, n = 60) and female (21%, n = 15) players and were employed across a variety of professional soccer leagues including English Premier League, Serie A, La Liga, Ligue 1, Bundesliga, Major League Soccer, and several others top tier competitions (e.g., Serbian Super League, Russian Premier league). The average experience of the coaches was 8 years (range 6 to 10 years) with S&C coaching qualifications held including NSCA-certified (41%, *n* = 26), UKSCA-certified (20%, *n* = 13), CSCA-certified (5%, *n* = 3), ASCA-certified (3%, *n* = 2), and "other" (47%, *n* = 30). Most of the participants held a master's degree (68%, *n* = 48), followed by a bachelor's degree (21%, *n* = 15) and a Doctor of Philosophy degree (11%, *n* = 8).

Importance of upper body strength for performance of high-intensity actions

Relative to "not important" options, the strength of UB muscles was perceived as important for all HIA (i.e., acceleration, maximal velocity, deceleration, COD, jumping, RSA), particularly for jumping (89%, *n* = 41) and acceleration (87%, *n* = 39), with RSA perceived least affected (66%, *n* = 27) (Table 1). Similarly, coaches agreed that strong UB would support jumping performance (100%, *n* = 31), acceleration (97%, n = 30), COD (93%, *n* = 27), RSA (91%, *n* = 21), maximal sprinting speed (90%, *n* = 27), and deceleration (85%, *n* = 22). Ranking order question revealed acceleration as the most influenced HIA by UB strength as seen by the surveyed coaches (32%, *n* = 17), followed by jumping (26%, *n* = 14), COD performance (19%, *n* = 10), maximal velocity sprinting (13%, *n* = 7), RSA (6%, *n* = 3), and deceleration (4%, n = 2). Notably, RSA was placed last in the highest number of instances (47%, *n* = 25). The reasons for ranking the chosen HIA as the most influenced by UB strength were mostly reflected in arm movements and trunk support (Table 2).

The percentage agreement on the importance of UB strength qualities (i.e., concentric, eccentric, isometric, reactive, maximal, relative, and explosive) for soccer players are presented in Table 3. All these qualities were rated as important. UB maximal strength had the lowest number of agreed responses, although the percentage of agreement was still very high (83%, *n* = 33) compared to those that disagreed (17%, *n* = 7). UB concentric strength and UB explosive strength had the highest agreement (98%, *n* = 45 for both options, respectively). Interestingly, when the proposed statements had negative connotations regarding UB strength influence towards soccer performance (e.g., "Upper body strength training will have too little specificity with the transfer to the soccer pitch"), coaches overwhelmingly disagreed with all of them (Table 4). Furthermore, many coaches agreed with the statements that UB strength training may help HIA via improved force transmissions (97%, *n* = 35) and increased neural drive (94%, *n* = 33), and only half of them believed that both training (50%, *n* = 13) and testing (54%, *n* = 14) of UB strength

Table 1. "Important" against "not important" selections regarding upper body strength contribution to high-intensity actions in professional soccer players as perceived by strength and conditioning coaches.

Order of importance	High-intensity action	Selected by respondents (*n*)	Selected by respondents (%)	Neutral (*n*)
1	Jumping	41	89	4
2	Acceleration	39	87	6
3	Maximal speed	37	79	3
4	Change of direction	37	79	7
5	Deceleration	33	67	7
6	Repeated sprint ability	27	66	9

**Percentages do not add up to 100% due to rounding and excluding the percentage of response frequencies that did not fit the groupings for perceptions (i.e., excludes percentage of responses "neutral")*

Table 2. Themes associated with perceptions on the importance of upper body strength training for performance of high-intensity actions as perceived by strength and conditioning coaches (number of responses in brackets).

Main Theme	Sub Theme	Indicative Participant Responses
Arm importance (12)	Arm drive for acceleration (5) and max velocity (1)	I feel it is important that the arm drive (at the shoulders) propels the body and supports the lower limb during acceleration phase. Reaching Max velocity required fast Arm work.
	Arm swing for jumping (6)	…a violent arm swing can be beneficial towards increasing jump height (both during the eccentric & concentric phases).
Trunk ("core") importance (11)	Stabilisation/control for various high-intensity actions (5)	I believe the stabilisation of the body by the core muscles will have a high impact in those actions.
	Force transmissions for change of direction (3) and other high-intensity actions (3)	Rotational forces through the trunk and upper body are highest during change of direction tasks and these muscles are important in counter balancing and creating the forces required to execute these movements. Having a strong core will link all body parts/limbs in order to generate power performing sporting movements.
Upper body importance (8)	Acceleration (2) and max velocity (1)	Stiffness of the upper body including the trunk when accelerating and sprinting.
	Jumping (2)	… although not indicative of power and technique, upper body strength is a forbearer for the aforementioned and allows for greater potential power.
	Change of direction (1)	Because of importance of upper body in movement when it comes from eccentric to concentric movement.
	Power generation (2)	Power, swing, strong movement… Because it experiences max efforts both of the whole body and of the upper part.

Table 3. "Important" against "not important" selections regarding upper body strength qualities' relevance for a professional soccer players as perceived by strength and conditioning coaches.

Order of importance	Strength quality	Selected by respondents (*n*)	Selected by respondents (%)	Neutral (*n*)
1	Concentric strength	44	98	3
2	Explosive strength	45	98	4
3	Eccentric strength	38	97	4
4	Relative strength	47	96	2
5	Isometric strength	41	95	5
6	Plyometric strength	35	90	9
7	Maximal strength	33	83	11

**Percentages do not add up to 100% due to rounding and excluding the percentage of response frequencies that did not fit the groupings for perception (i.e., excludes percentage of responses "neutral").*

Table 4. "Agree" against "disagree" selections by strength and conditioning coaches for the proposed statements.

Order of agreement	Statement	Selected by respondents (*n*)	Selected by respondents (%)	Neither agree nor disagree (*n*)
1	Upper body strength training lacks specificity for soccer.	11	42	21
2	Upper body strength training will take precious time from other sessions.	6	21	7
3	Upper body strength training will reduce overall recovery from other sessions.	6	20	7
4	Upper body strength training will result in higher bodyweight jeopardising performance.	4	13	8
5	Upper body strength training will cause unnecessary fatigue.	2	6	11
6	Upper body strength training will increase the risk of injury.	2	5	2

**Percentages do not add up to 100% due to rounding and excluding the percentage of response frequencies that did not fit the groupings for agreement (i.e., excludes percentage of responses "neither agree nor disagree").*

Table 5. "Agree" against "disagree" selections by strength and conditioning coaches for the proposed statements.

Order of agreement	Statement	Selected by respondents (*n*)	Selected by respondents (%)	Neither agree nor disagree (*n*)
1	Upper body strength training may improve physical duels.	36	100	4
2	Upper body strength training may help high intensity actions via improved force transmissions	35	97	4
3	Upper body strength training may help high intensity actions via improved neural drive	33	94	5
4	Upper body strength training reduces the risk of injury	21	81	12
5	Upper body strength testing should be highly specific with the exercise selection	14	54	14
6	Upper body strength training should be highly specific with the exercise selection	13	50	13
7	Current upper body strength trainings in soccer do not result in meaningful neuromuscular adaptations	10	37	14

**Percentages do not add up to 100% due to rounding and excluding the percentage of response frequencies that did not fit the groupings for agreement (i.e., excludes percentage of responses "neither agree nor disagree")*

should be highly specific with the exercise selection (Table 5). Of note, the statement "upper body strength training for soccer population do not result in meaningful neuromuscular adaptations" was the least supported (37%, *n* = 10).

Upper body strength testing and training practices

Maximal UB strength was the most frequently tested variable (73%, *n* = 29), followed by concentric strength (68%, *n* = 27), explosive strength (60%, *n* = 24), isometric strength (50%, *n* = 20), and reactive strength (35%, *n* = 14). Interestingly, however, the most reported strength test was medicine ball throw (26%, *n* = 11). This was followed by one repetition maximum (1-RM) bench press (19%, *n* = 8), ballistic bench throw (12%, *n* = 5), 1-RM chin-ups/pull-ups (12%, *n* = 5), plank holds (9%, *n* = 4), chest press (7%, *n* = 3), bench pulls (5%, *n* = 2), plyometric push-ups (5%, n = 2), isometric bench press (2%, *n* = 1), chin-up hold (2%, *n* = 1) and push-up hold (2%, *n* = 1).

Figure 1 shows the percentage of various UB exercises prescribed by S&C coaches working with professional soccer players. The "pull-ups and variations" were selected in the highest number of instances (90%, *n* = 36), while "front raises" were the least selected (25%, *n* = 10). The most important reasons for prescribing UB exercises were to withstand physical duels and increase overall athleticism (Table 6). Somewhat surprisingly, 62% agreed (*n* = 18) that the greatest focus of UB resistance sessions that I prescribe is on core muscles", reflecting the emphasis that S&C coaches currently place on the training of this muscle group (Figure 2). This was in agreement with the coaches' perceived importance of targeting trunk flexion

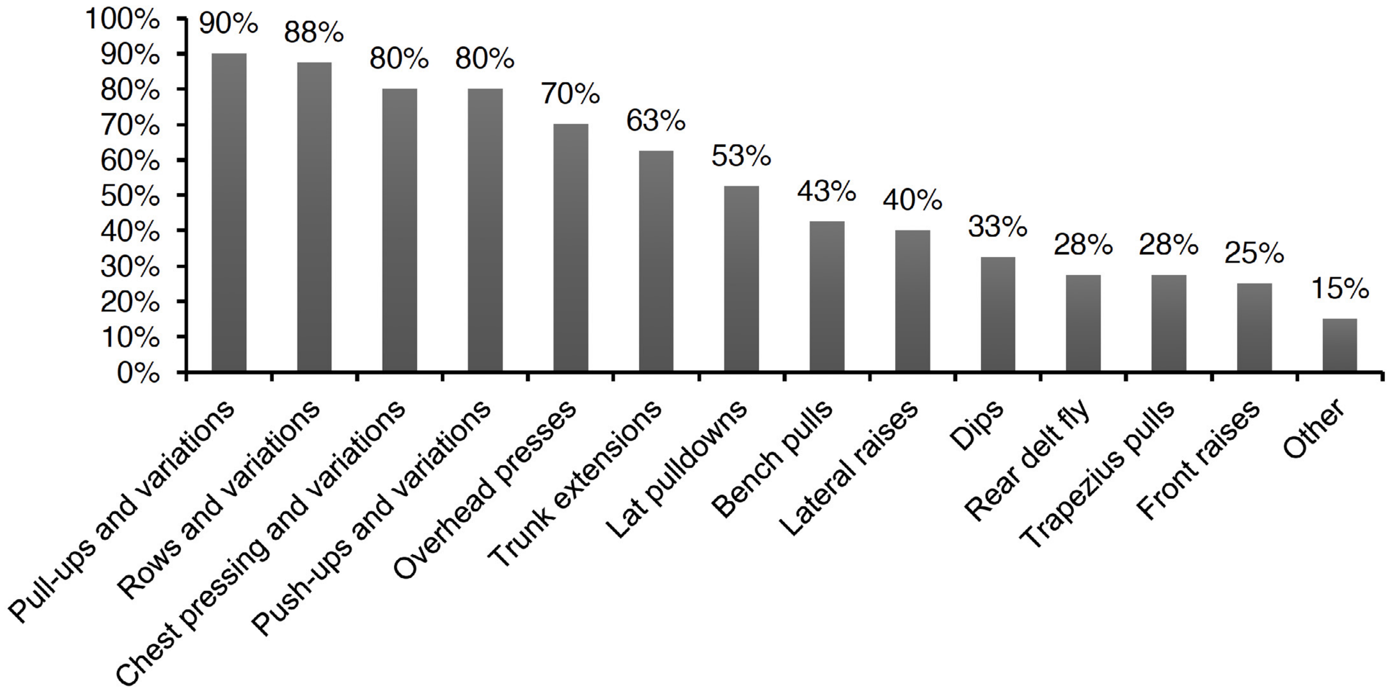

Figure 1. Upper body exercises prescribed by strength and conditioning coaches working with professional soccer players.

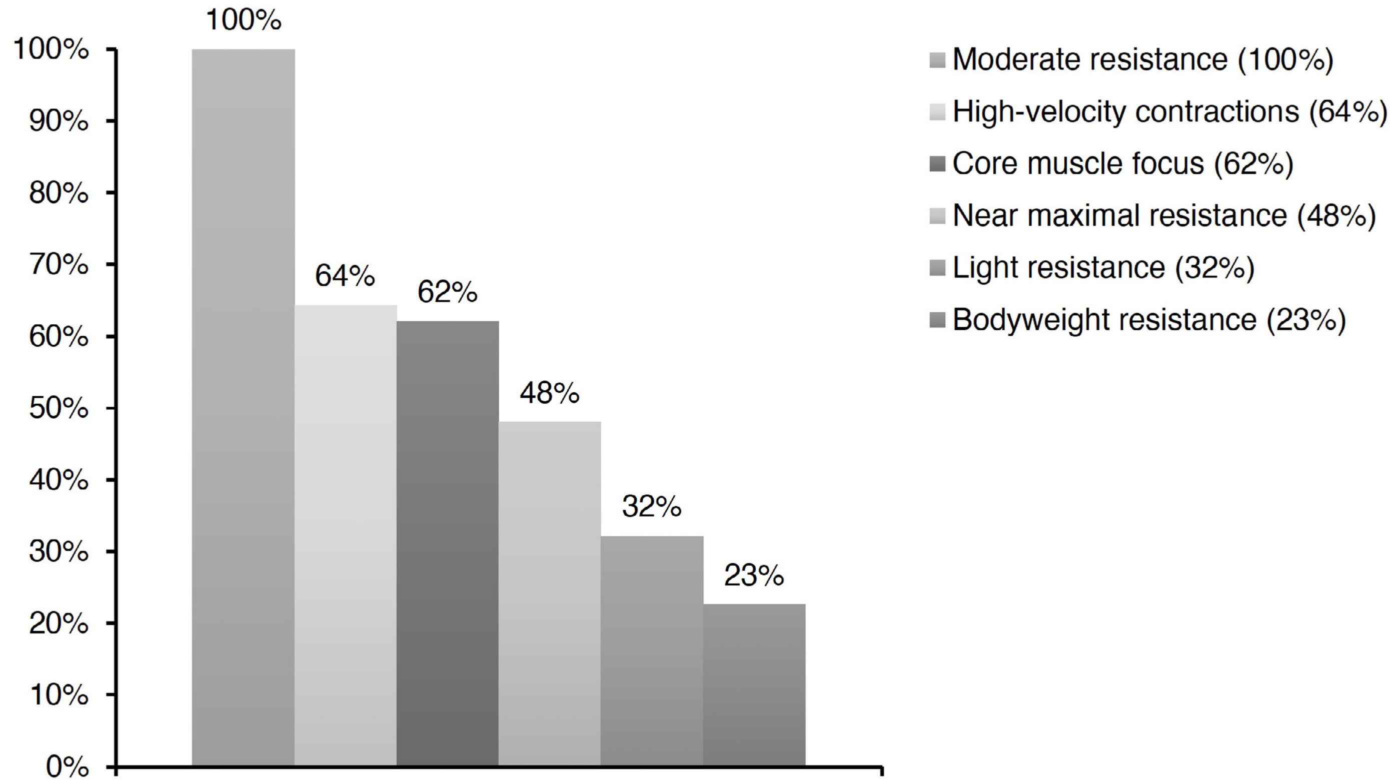

Figure 2. The percentage of "agree" relative to "disagree" responses on the proposed statements regarding the most frequently utilised upper body strength training type and resistance. Note: Light resistance = <60% 1-RM, moderate resistance = 60-80% 1-RM, near maximal resistance = >80% 1-RM.

(94%, *n* = 32), trunk extension (97%, *n* = 34), and torso rotations (97%, *n* = 34), before the arm drive (83%, *n* = 24) to facilitate body movements relevant for the performance of HIA.

Surveyed practitioners mostly prescribe UB exercises either after LB resistance sessions within the same day (81%, *n* = 17) or as a part of whole-body sessions (81%, *n* = 25) (Table 7). With regards to exercise intensity, coaches primarily use moderate resistance (60-80% of 1-RM) (100%, *n* = 30) rather than near-maximal resistance (>80% of 1-RM) (48%, *n* = 12) or light resistance (<60% of 1-RM) (32%, *n* = 9). Only 64% (*n* = 17), preferably utilise high-velocity contractions (Figure 2). The only exercise combination that the surveyed coaches would be hesitant to implement is placing the UB strength session before the LB strength session, while all other options were overwhelmingly supported (Table 8). As perceived by their coaches, it seems that soccer players have a high motive to engage in UB workouts, mostly to improve self-confidence and wellbeing (Table 6).

UB training sessions are preferably included one day post-match (59%, *n* = 23) or two days before the match (56%, *n* = 22), with the least number of coaches prescribing it one day before the match (13%, *n* = 5). Furthermore, UB strength is preferably trained two times a week in both pre-season (60%, *n* = 24) and in-season (55%, *n* = 22), with a smaller percentage of coaches prescribing it three times a week in pre-season (35%, *n* = 14), and once a week in-season (35%, *n* = 14). This was somewhat contradictory to their overall perception that UB relative strength needs more dedication in practice, moving away from the fear it would make players slower and bigger (Table 9). It is possible that the coaches counted UB strength sessions whenever this region would be active during the whole-body workouts because only 32% of respondents (*n* = 13) believed that these muscles needed a separate session for a notable strength improvement.

Table 6. Themes associated with reasons for prescribing upper body strength exercises for professional soccer players by strength and conditioning coaches (number of responses in brackets).

Main Theme	Sub Theme	Indicative Participant Responses
Performance of high-intensity actions (9)	Sprinting performance (2)	Because of the upper posterior chain musculature involved in sprinting.
	Acceleration performance (3)	Indirectly support them during acceleration.
	Jumping performance (3)	Support during jumping movements.
	Change of direction performance (1)	The upper part of the body helps to change direction.
Performance improvement (35)	Physical duels (12)	Because they will need to fight for position when chasing down a ball or fighting off defenders whilst maintaining possession of the ball. …enough strength and power to beat the opponent during the fight actions, to keep the ball under opponent pressing, to try to steal the ball from an opponent, to keep the ball's control during a maximal sprint fighting with an opponent…
	Overall athleticism (8)	It is part of a balanced training program to improve players' overall athleticism and robustness. To develop globally the athletic aspect of the soccer player. For comprehensive strength development throughout the entire body and the synergy that comes with it.
	Stability/balance (6)	…to hold postures and positions. …lumbar health…
	Neural drive (3)	…to aid in neural adaptations i.e., power development…
	Recovery (3)	Important in the recovery phase for the hormonal response.
	Injury prevention (3)	Injury prevention - physical contacts with opposing players. …for injury prevention, for both GK's and outfield players when falling/diving on the floor.
Morphological change (7)	Fat reduction (4) Hypertrophy gains (3)	…the main goal is to control the anthropometric measures, to decrease the body fat mass, and to increase the muscle mass for the players who need it.
Players' wellbeing (8)	Increase confidence/feel better (5)	To feel better. …overall perception of players capability to „move" objects - perception of being strong. To develop globally the athletic aspect of the soccer player, improve self-confidence.
	Players' preferences (3)	…the lads like it for aesthetics. …to have a good body.

Table 7. "Agree" against "disagree" selections by strength and conditioning coaches for the proposed statements regarding their preferable upper body strength training positioning relative to other exercise sessions.

Order of agreement	Statement	Selected by respondents (*n*)	Selected by respondents (%)	Neither agree nor disagree (*n*)
1	After the lower body resistance session in the same day.	25	81	10
2	As a part of whole-body resistance sessions.	25	81	10
3	After the cardio-respiratory endurance session in the same day.	17	77	9
4	Before the cardio-respiratory endurance session in the same day.	9	41	19
5	Before the lower body resistance session in the same day.	6	23	13

**Percentages do not add up to 100% due to rounding and excluding the percentage of response frequencies that did not fit the groupings for agreement (i.e., excludes percentage of responses "neither agree nor disagree").*

Table 8. Strength and conditioning coaches who selected "yes" to the proposed statements regarding positioning of upper body strength training in professional soccer (n = 40).

Order of agreement	Statement	Selected by respondents (*n*)	Selected by respondents (%)
1	As a part of whole-body resistance sessions.	35	88
2	After the lower body resistance session in the same day.	32	80
3	After the cardio-respiratory endurance session in the same day.	32	80
4	Before the cardio-respiratory endurance session in the same day.	22	73
5	Before the lower body resistance session in the same day.	17	43

**Percentages do not add up to 100% due to rounding to whole numbers.*

Table 9. Themes associated with the potential issues surrounding upper body strength training for soccer players as perceived by strength and conditioning coaches.

Main Theme	Sub Theme	Indicative Participant Responses
Lack of understanding specific strength training effects within soccer (9)	Relative strength perspective understanding (4)	I believe they should be pound for pound as strong as possible so for me it is really directed to their relative strength to their body weight.
	Fear of being bigger and slower (3)	The major problem revolves around certain players and Head Coach who believe that upper body strength training will make them bigger and slower on pitch. Players usually avoid lifting heavy as they think it is not necessary, but that does not lead to proper stimulus needed for them to improve their strength.
		…fear of getting „too big"- intensity distribution/prescription - knowledge about strength training in general.
	Players not informed (2)	The players are not familiarising with the upper body work.
Programming issues (10)	Insufficient upper body exercise presence (5)	Not enough overhead work. Too many shy away from working on rom and force capacity.
		Upper body need more training.
		More use of free weights.
		High load need.
	Need for individualisation (2)	High individualisation is required when it comes to upper body strength.
	In-season positioning (1)	Difficult to programme sometimes in season, especially on 2 game weeks.
	Need for simplicity (1)	Simple exercise selection and programming solutions in the weight room.
	Disbalance in upper body activation (1)	…maybe often an emphasis on pushing over pulling exercises.

DISCUSSION

This is the first study that aimed to investigate the perception of S&C coaches on the importance of UB strength and UB strength training for the performance of HIA (i.e., sprinting, repeated sprint ability, change of direction, and jumping) in professional soccer players, and to identify current practices with regards to UB strength testing and training methodologies within this sport. Relative to "not important" options, UB strength was perceived as important for all HIA, especially for jumping (89%) and acceleration (87%). Coaches strongly supported the idea that UB strength plays a role in enhancing HIA, with particular influence on jumping (100%), acceleration (97%) and COD (93%). This influence is believed to be realised via improved force transmissions (97%) and neural drive (94%). However, surveyed coaches overwhelmingly use moderate resistance in their sessions (100%) without substantial emphasis on high-velocity contractions (64%). UB exercises are mostly included either concurrently with or after LB resistance training sessions. More research is warranted to explore the potential of UB strength training for the improvement and recovery of HIA performance in professional soccer players.

The finding that UB strength training is perceived as important for enhancing short sprint performance via arm movements and trunk support provides interesting perspectives that have not previously been investigated in soccer players. Ingebritsen and Jeffreys [28] reported no association between 1-RM bench press and 10-m sprints in young handball players, while Young et al. [7] reported negative associations (*r* = -0.41) between greater 3-RM bench press and "flying" 30-m sprint times in Australian football players suggesting that greater UB maximal strength may contribute to faster sprinting speeds [7]. It could be argued that sprint acceleration is highly dependent on a body's relative strength ability to deal with its inertia [63], whereas the absolute strength perspective may appear more important for the maximum velocity phase [7]. Notably, greater strength measures could be wrongly associated with worsened HIA performance if body fat percentage is not accounted for [64, 65]. This is especially an important factor for speed endurance-related qualities such as RSA [66, 67], which could be one of the reasons why coaches from this study perceived RSA to be the least influenced by higher UB strength levels. However, previous research investigating RSA performance has reported large positive associations with greater 1-RM relative bench press strength for handball [28], basketball [8], rugby and soccer players [27]. This positive influence on RSA may be explained by the ability of stronger individuals to experience less central fatigue [68] during repetitive contractions due to producing more power output with less neural cost [69], allowing them to maintain the same level of voluntary effort for longer periods.

In this study, S&C coaches placed a considerable emphasis on exercises targeting trunk muscles during UB training sessions. These exercises are prescribed mostly for their stabilising and balancing role (Table 6). That said, a systematic review with meta-analysis by Prieske et al. [70] concluded that there was a limited association between "core" muscles (mostly evaluated by their stabilising role via strength-endurance assessments) and various metrics of athletic performance. While static trunk exercises might, therefore, be less impactful [30], dynamic trunk strength training could be more influential for HIA performance in soccer players [71], particularly through mechanisms aligned to greater trunk extensor strength [29–31, 72–74]. For example, jumping performance is worsened when trunk extensors are fatigued beforehand [73] or when their activation is limited through a straightened trunk before the jump [75, 76]. Furthermore, trunk muscles are the main force transmitters between UB and LB in COD [34, 77], and RFD of these muscles may assist with rapid transformations from eccentric to isometric and concentric phases in COD movement patterns [20, 77]. This may explain why greater maximal isometric strength of all trunk muscles may lead to better COD performances [33].

Maximal strength of UB muscles was perceived as the least important quality by the surveyed practitioners, although its importance was still considered high. Interestingly, however, this type of strength quality is most frequently tested among the study respondents, utilising bench press as a primary test. This is consistent with the findings from a systematic review examining strength and power assessment practices in elite soccer [52] which found UB strength testing to be extremely rare and exclusively limited to bench press. Furthermore, contrary to concerns about specificity, which states that the training should mirror movement patterns typical for the activity being trained [78], practitioners expressed confidence in the efficacy of UB training for its transferability to HIA and soccer performance. In accordance, 94% of the participants believe that UB strength training helps with increased neural drive for HIA.

Maximal strength underpins RFD [79] and high neural activation with the intention to produce rapid contractions could lead to the improvement of force generation regardless of the movement pattern specificity [78]. Yet, despite valuing UB strength training's role for enhanced neural adaptations, the surveyed practitioners overwhelmingly use moderate resistance in their sessions (100%) while only around half of them (64%) utilise high-velocity contractions. Hence, it is questionable how much impact these sessions could have on UB power improvements [41], a quality which is typically trained with either a maximal strength or maximal velocity approach [42].

McQuilliam et al. [50] revealed that soccer S&C practitioners from the United Kingdom regarded bodyweight training (e.g., press-ups) as the most important training modality. Notably, this type of exercise lacks a sufficient stimulus for the development of maximal strength compared to free weights [80]. Nonetheless, over half of the surveyed coaches (63%) did not agree with the statement that current UB resistance training in soccer does not result in meaningful neuromuscular adaptations. Contradictorily, insufficient UB exercise presence in typical soccer training regimes was one of the main subthemes around potential issues surrounding UB strength training for soccer players (Table 9). The respondents suggested this could be due to the fear of players becoming "bigger and slower", a lack of knowledge around the relative strength influence, and players not being appropriately informed about the importance of UB strength training for HIA and soccer performance.

A high percentage of S&C coaches prescribed UB strength training two times a week, although UB programming strategies were less clear. For example, only 33% believe that UB muscles need a separate strength training session to achieve notable strength improvements. There is only one study in the literature, to the authors' knowledge, that prescribed a separate UB strength training session in addition to other training sessions for professional soccer players [35]. This investigation reported that dedicating a single session per week focused solely on UB strength could be sufficient for achieving notable gains [35], likely reflecting underdeveloped strength in this body area. Indeed, a survey exploring contemporary practices of S&C coaches in professional soccer [49] reported that the main focus of resistance training sessions was LB exercises, while UB exercises such as bench press, overhead press, pull-ups and lateral pulldowns had less emphasis [49]. Thus, it does not come as a surprise that the UB strength of professional soccer players [35, 37, 81] seems to be much lower than that of other team sport athletes [65, 82, 83], which cannot be stated for the leg strength [84]. Sabag et al. [41] warned that neuromuscular adaptations from UB resistance sessions may be lacking in soccer in its current format, which could possibly result in a lower power-generating capacity for HIA compared to other team sport athletes [9].

For the surveyed S&C coaches, UB strength training predominantly occurs either immediately following (81%) or concurrently with LB resistance training sessions (81%), typically employing moderate resistance (100%). Consequently, the physiological adaptations stemming from these sessions may be somewhat limited [85]. In contrast, sufficiently intensive resistance sessions for multiple UB muscle groups incorporated alongside LB exercises could result in augmented strength responses from both LB muscles [86] and UB muscles [87, 88], likely due to the stimulated circulating factors that facilitate beneficial muscle adaptations on a whole-body level [89]. For example, a group of soccer players who followed traditional full-body strength training sessions with the emphasised activation of UB muscles demonstrated greater efficiency in enhancing HIA performances (i.e., 20-m sprint, COD, squat jump) compared to both the sprint & jump-only training group and a "functional" training group with lighter resistance [90].

The majority of S&C coaches from this study would avoid deploying UB strength sessions before the LB session, probably to avoid fatigue interfering with the main target of strength training (i.e., leg muscles), which is a logical and rational consideration. Intriguingly, however, when a single muscle from the LB is to be trained (i.e., quadriceps), it is possible that preceding comprehensive high-volume training of UB muscles could facilitate androgen response from that (leg) muscle [91, 92], potentially contributing to positive muscle remodelling. This suggests a promising direction for further research on interventions that enable the development of effective UB training strategies for the recovery processes and enhanced adaptations of LB muscles.

Coaches from this study revealed that soccer players like to exercise their upper bodies, mostly to boost their confidence and well-being, which could be an important consideration regarding the motivation of the players to engage in short but intensive UB workouts after LB-focused sessions. In agreement, 80% of the surveyed practitioners would consider adding UB strength training after the leg resistance session. Furthermore, it looks important for players to understand the benefits of added UB strength training to approach it with the needed attention. For example, a comprehensive engagement of multiple UB muscle groups placed after a fatiguing running session might preserve leg muscle morphology from a catabolic environment [18, 93] due to the stimulated neurophysiological responses [17]. These mechanisms might also support strength adaptations from strength-trained UB muscles trained before high-volume leg resistance sessions [87]. Therefore, UB strength training might need to be reassessed with its potential to affect remote muscle groups via vertical strength transfer [17] and aid to overall athletic performance on account of facilitated neurophysiological adaptations.

In conclusion, this study reveals that soccer S&C coaches consider UB strength important for all HIA, especially for acceleration, jumping and COD. Surveyed practitioners value UB strength training's role primarily through neuromuscular adaptations that support whole-body force generation. Nevertheless, when compared to near-maximal resistance and high-velocity contractions, it seems that coaches prefer the use of moderate resistance with unspecified velocities, which questions the level of neuromuscular adaptations arriving from these sessions. These (UB) exercises are commonly integrated either after LB sessions or within the whole-body sessions, but rarely alone or before the LB training sessions. Furthermore, despite the high recognition of other UB strength qualities, surveyed coaches primarily utilise 1-RM strength assessments. Overall findings warrant the need for further research to fully exploit the potential of UB strength training for supporting HIA performance in soccer players. This may be realised via correlational studies utilising various UB strength tests and HIA tests as well as through UB strength training interventions across a dedicated time sufficient to induce meaningful neurophysiological adaptations with the potential influence towards HIA performances.

PRACTICAL APPLICATIONS

Soccer S&C coaches believe that UB strength training holds an important place for facilitating HIA performance. It is recommended that relative strength capacity in the UB region should be trained with differential approaches (i.e., concentric, explosive, reactive, isometric, eccentric, maximal) in a dedicated session placed after LB resistance training to positively contribute to neurophysiological adaptations on a whole-body level. UB strength is highly valued for its role in physical duels via greater stability and for leg-dominant HIA via improved force transmissions and enhanced neural drive. Therefore, practitioners may want to consider emphasising UB strength and UB power improvement for their soccer players to maximise HIA performance on a soccer pitch. Future studies should explore the degree to which UB strength training may affect HIA and identify the potential mechanisms through which this influence may occur.

ACKNOWLEDGMENTS

Data availability does not apply to this manuscript. The authors received no financial support, nor did they have any conflicts of interest relevant to this article.

All five authors contributed to the design and implementation of the study; IC completed the analysis of the results and original writing of the manuscript; DH, JA, DR, and DG edited and reviewed the writing of the manuscript; DH was the director of the study.

CONFLICTS OF INTEREST

There are no conflicting relationships or activities.

FUNDING

This study received no specific funding in order to be completed.

ETHICAL APPROVAL

Ethical approval for the study was granted by the University of Central Lancashire ethics committee (REF: HEALTH 0330 Phase_3) in line with the principles of the Helsinki Declaration (2013). Coaches were notified that they could receive a copy of the results upon request.

DATES OF REFERENCE

Submission - 05/07/2024

Acceptance - 09/10/2024
Publication - 31/01/2025

CORRESPONDING AUTHOR

Ivan Curovic - icurovic@uclan.ac.uk

REFERENCES

1. Faude O, Koch T, Meyer T. Straight sprinting is the most frequent action in goal situations in professional football. Journal of Sports Sciences 2012; 30: 625–631.
2. Nedelec M, McCall A, Carling C, et al. The influence of soccer playing actions on the recovery kinetics after a soccer match. Journal of strength and conditioning research 2014; 28: 1517–1523.
3. Filter A, Olivares-Jabalera J, Dos'Santos T, et al. High-intensity actions in elite soccer: current status and future perspectives. International journal of sports medicine. Epub ahead of print 2023. DOI: 10.1055/a-2013-1661.
4. Baptista I, Johansen D, Seabra A, et al. Position specific player load during match-play in a professional football club. PLoS ONE 2018; 13: e0198115.
5. Harper DJ, Carling C, Kiely J. High-intensity acceleration and deceleration demands in elite team sports competitive match play: a systematic review and meta-analysis of observational studies. Sports medicine (Auckland, NZ); 49. Epub ahead of print December 2019. DOI: 10.1007/s40279-019-01170-1.
6. Harper D, Sandford G, Clubb J, et al. Elite Football of 2030 will not be the same as that of 2020: What has evolved and what needs to evolve? 2020.
7. Young WB, Newton RU, Doyle TL, et al. Physiological and anthropometric characteristics of starters and non-starters and playing positions in elite Australian Rules Football: a case study. Journal of science and medicine in sport 2005; 8: 333–345.
8. Balsalobre-Fernández C, Tejero-González C, Campo-Vecino J, et al. Relationships among repeated sprint ability, vertical jump performance and upper-body strength in professional basketball players. Archivos de Medicina del Deporte 2014; 31: 148–153.
9. Loturco I, Pereira LA, Reis VP, et al. Change of direction performance in elite players from different team sports. Journal of strength and conditioning research 2022; 36: 862–866.
10. Hinrichs RN. Upper extremity function in running. II: Angular momentum considerations. Journal of Applied Biomechanics 1987; 3: 242–263.
11. Walsh MS, Böhm H, Butterfield MM, et al. Gender bias in the effects of arms and countermovement on jumping performance. Journal of strength and conditioning research 2007; 21: 362–366.
12. Walsh MS, Waters JA, Böhm H, et al. Gender bias in jumping kinetics in National Collegiate Athletic Association Division I basketball players. Journal of strength and conditioning research 2007; 21: 958–962.
13. Hara M, Shibayama A, Takeshita D, et al. A comparison of the mechanical effect of arm swing and countermovement on the lower extremities in vertical jumping. Human Movement Science 2008; 27: 636–648.
14. Nagahara R, Mizutani M, Matsuo A, et al. Association of Sprint Performance With Ground Reaction Forces During Acceleration and Maximal Speed Phases in a Single Sprint. Journal of applied biomechanics 2018; 34: 104–110.
15. Weyand PG, Sternlight DB, Bellizzi MJ, et al. Faster top running speeds are achieved with greater ground forces not more rapid leg movements. Journal of applied physiology (Bethesda 2000; 89: 1991–1999.
16. Shield S, Jericevich R, Patel A, et al. Tails, Flails, and Sails: How Appendages Improve Terrestrial Maneuverability by Improving Stability. Integrative and comparative biology 2021; 61: 506–520.
17. Curovic I, Rhodes D, Alexander J, et al. Vertical Strength Transfer Phenomenon Between Upper Body and Lower Body Exercise: Systematic Scoping Review. Sports Med. Epub ahead of print 14 May 2024. DOI: 10.1007/s40279-024-02039-8.
18. Abaïdia A-E, Delecroix B, Leduc C, et al. Effects of a Strength Training Session After an Exercise Inducing Muscle Damage on Recovery Kinetics. J Strength Cond Res 2017; 31: 115–125.
19. Jaric S, Ristanovic D, Corcos DM. The relationship between muscle kinetic parameters and kinematic variables in a complex movement. European journal of applied physiology and occupational physiology 1989; 59: 370–376.
20. Maffiuletti NA, Aagaard P, Blazevich AJ, et al. Rate of force development: physiological and methodological considerations. Eur J Appl Physiol 2016; 116: 1091–1116.
21. Rhodes D, Valassakis S, Eaves R, et al. The Effect of High-Intensity Accelerations and Decelerations on Match Outcome of an Elite English League Two Football Team. International Journal of Environmental Research and Public Health; 18. Epub ahead of print 21 September 2021. DOI: 10.3390/ijerph18189913.
22. Wing CE, Turner AN, Bishop CJ. Importance of Strength and Power on Key Performance Indicators in Elite Youth Soccer. Journal of Strength and Conditioning Research 2020; 34: 2006–2014.
23. Forcher L, Forcher L, Altmann S, et al. The keys of pressing to gain the ball – Characteristics of defensive pressure in elite soccer using tracking data. Science and Medicine in Football 2022; 1–9.
24. Sleivert G, Taingahue M. The relationship between maximal jump-squat power and sprint acceleration in athletes. European journal of applied physiology 2004; 91: 46–52.

25. Harper DJ, Jordan AR, Kiely J. Relationships between eccentric and concentric knee strength capacities and maximal linear deceleration ability in male academy soccer players. Journal of strength and conditioning research 2021; 35: 465–472.
26. Wisløff U, Castagna C, Helgerud J, et al. Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. British journal of sports medicine 2004; 38: 285–288.
27. Durandt J, Tee JC, Prim SK, et al. Physical fitness components associated with performance in a multiple-sprint test. Int J Sports Physiol Perform 2006; 1: 150–160.
28. Ingebrigtsen J, Jeffreys I. Relationship between speed, strength and jumping abilities in elite junior handball players. Serbian Journal of Sports Sciences; 6.
29. Kubo T, Hoshikawa Y, Muramatsu M, et al. Contribution of Trunk Muscularity on Sprint Run. Int J Sports Med 2011; 32: 223–228.
30. Genc H, Cigerci AE, Sever O. Effect of 8-week core training exercises on physical and physiological parameters of female handball players. Physical Education of Students 2019; 23: 297–305.
31. Prieske O, Muehlbauer T, Krueger T, et al. Role of the trunk during drop jumps on stable and unstable surfaces. Eur J Appl Physiol 2015; 115: 139–146.
32. Blache Y, Monteil K. Effect of arm swing on effective energy during vertical jumping: experimental and simulation study. Scandinavian journal of medicine & science in sports 2013; 23: 121–129.
33. Kozinc Ž, Smajla D, Šarabon N. The relationship between lower limb maximal and explosive strength and change of direction ability: Comparison of basketball and tennis players, and long-distance runners. PLoS One 2021; 16: e0256347.
34. Hewit J, Cronin J, Button C, et al. Understanding Change of Direction Performance via the 90° Turn and Sprint Test. Strength & Conditioning Journal 2010; 32: 82.
35. Hertzog M, Rumpf MC, Hader K. Resistance training status and effectiveness of low-frequency resistance training on upper-body strength and power in highly trained soccer players. Journal of strength and conditioning research 2020; 34: 1032–1039.
36. McIntyre MC. A comparison of the physiological profiles of elite Gaelic footballers, hurlers, and soccer players. British Journal of Sports Medicine 2005; 39: 437–439.
37. Wisløff U, Helgerud J, Hoff J. Strength and endurance of elite soccer players: Medicine &amp Science in Sports &amp Exercise 1998; 30: 462–467.
38. Baker D. Comparison of upper-body strength and power between professional and college-aged rugby league players. J Strength Cond Res 2001; 15: 30–35.
39. Bilsborough JC, Greenway K, Livingston S, et al. Changes in anthropometry, upper-body strength, and nutrient intake in professional Australian football players during a season. International journal of sports physiology and performance; 11.
40. Robbins DW. Relationships between National Football League combine performance measures. Journal of strength and conditioning research 2012; 26: 226–231.
41. Sabag A, Lovell R, Walsh NP, et al. Upper-body resistance training following soccer match play: compatible, complementary, or contraindicated? International journal of sports physiology and performance 2021; 16: 165–175.
42. Cormie P, McGuigan MR, Newton RU. Developing Maximal Neuromuscular Power: Part 2 – Training Considerations for Improving Maximal Power Production. Sports Medicine 2011; 41: 125–146.
43. Maurya PS, Sisneros KP, Johnson EB, et al. Reliability of handgrip strength measurements and their relationship with muscle power. J Sports Med Phys Fitness 2023; 63: 805–811.
44. Sisneros K, Maurya P, Johnson E, et al. Age-related Differences in Handgrip Strength Characteristics and Vertical Jump Performance. International Journal of Exercise Science: Conference Proceedings; 2, https://digitalcommons.wku.edu/ijesab/vol2/iss15/35 (2023).
45. Labott BK, Donath L. Agility performance in healthy older adults is associated with handgrip strength and force development: results from a 1-year randomized controlled trial. Eur Geriatr Med 2023; 14: 547–555.
46. Suarez-Arrones L, Saez De Villarreal E, Núñez FJ, et al. In-season eccentric-overload training in elite soccer players: Effects on body composition, strength and sprint performance. PLoS ONE 2018; 13: e0205332.
47. Christou M, Smilios I, Sotiropoulos K, et al. Effects of Resistance Training on the Physical Capacities of Adolescent Soccer Players. J Strength Cond Res 2006; 20: 783.
48. Loturco I, Pereira LA, Kobal R, et al. Half-squat or jump squat training under optimum power load conditions to counteract power and speed decrements in Brazilian elite soccer players during the preseason. Journal of Sports Sciences 2015; 33: 1283–1292.
49. Weldon A, Duncan MJ, Turner A, et al. Contemporary practices of strength and conditioning coaches in professional soccer. bs 2021; 38: 377–390.
50. McQuilliam SJ, Clark DR, Erskine RM, et al. Global differences in current strength and conditioning practice within soccer. International Journal of Sports Science & Coaching 2024; 19: 182–191.
51. McQuilliam SJ, Clark DR, Erskine RM, et al. Physical testing and strength and conditioning practices differ between coaches working in academy and first team soccer. International Journal of Sports Science & Coaching 2023; 18: 1045–1055.
52. Asimakidis ND, Mukandi IN, Beato M, et al.

Assessment of Strength and Power Capacities in Elite Male Soccer: A Systematic Review of Test Protocols Used in Practice and Research. Sports Med. Epub ahead of print 18 July 2024. DOI: 10.1007/s40279-024-02071-8.
53. Rampinini E, Sassi A, Morelli A, et al. Repeated-sprint ability in professional and amateur soccer players. Appl Physiol Nutr Metab 2009; 34: 1048–1054.
54. Harper LD, McCunn R. “Hand in Glove”: Using Qualitative Methods to Connect Research and Practice. International Journal of Sports Physiology and Performance 2017; 12: 990–993.
55. McNeill C, Beaven CM, McMaster DT, et al. Survey of Eccentric-Based Strength and Conditioning Practices in Sport. The Journal of Strength & Conditioning Research 2020; 34: 2769.
56. Simenz C, Dugan C, Ebben W. Strength and Conditioning Practices of National Basketball Association Strength and Conditioning Coaches. Journal of strength and conditioning research / National Strength & Conditioning Association 2005; 19: 495–504.
57. Burton AM, Eisenmann JC, Cowburn I, et al. Developing motor competency in youths: Perceptions and practices of strength and conditioning coaches. J Sports Sci 2021; 39: 2649–2657.
58. Thomas DR. A General Inductive Approach for Analyzing Qualitative Evaluation Data. American Journal of Evaluation 2006; 27: 237–246.
59. Naeem M, Ozuem W, Howell K, et al. A Step-by-Step Process of Thematic Analysis to Develop a Conceptual Model in Qualitative Research. International Journal of Qualitative Methods 2023; 22: 16094069231205789.
60. de Farias BG, Dutra-Thomé L, Koller SH, et al. Formulation of Themes in Qualitative Research: Logical Procedures and Analytical Paths. Trends in Psychol 2021; 29: 155–166.
61. Vagias WM. Likert-type scale response anchors. clemson international institute for tourism. & Research Development, Department of Parks, Recreation and Tourism Management, Clemson University 2006; 4–5.
62. Mirzaei A, Carter SR, Patanwala AE, et al. Missing data in surveys: Key concepts, approaches, and applications. Res Social Adm Pharm 2022; 18: 2308–2316.
63. Young W, Benton D, John Pryor M. Resistance training for short sprints and maximum-speed sprints. Strength & Conditioning Journal 2001; 23: 7.
64. Abe T, Kawamoto K, Dankel SJ, et al. Longitudinal associations between changes in body composition and changes in sprint performance in elite female sprinters. European Journal of Sport Science 2020; 20: 100–105.
65. Sporis G, Vuleta D, Vuleta D Jr, et al. Fitness profiling in handball: physical and physiological characteristics of elite players. Collegium antropologicum 2010; 34: 1009–1014.
66. Brocherie F, Girard O, Forchino F, et al. Relationships between anthropometric measures and athletic performance, with special reference to repeated-sprint ability, in the Qatar national soccer team. Journal of Sports Sciences 2014; 32: 1243–1254.
67. Campa F, Semprini G, Júdice PB, et al. Anthropometry, Physical and Movement Features, and Repeated-sprint Ability in Soccer Players. Int J Sports Med 2019; 40: 100–109.
68. Taylor JL, Todd G, Gandevia SC. Evidence for a supraspinal contribution to human muscle fatigue. Clinical and experimental pharmacology & physiology 2006; 33: 400–405.
69. Jenkins NDM, Miramonti AA, Hill EC, et al. Greater Neural Adaptations following High- vs. Low-Load Resistance Training Frontiers in physiology 2017; 8: 331.
70. Prieske O, Muehlbauer T, Granacher U. The Role of Trunk Muscle Strength for Physical Fitness and Athletic Performance in Trained Individuals: A Systematic Review and Meta-Analysis. Sports Med 2016; 46: 401–419.
71. Bayrakdar A, Boz HK, Işildar Ö. The Investigation of the Effect of Static and Dynamic Core Training on Performance on Football Players. turkish journal of sport and exercise, https://www.semanticscholar.org/paper/The-Investigation-of-the-Effect-of-Static-and-Core-Bayrakdar-Boz/e519c3e5e126c774136d164b20f72d82435c466b (2020, accessed 11 February 2024).
72. Ben Moussa Zouita A, Ben Salah FZ, Dziri C, et al. Comparison of isokinetic trunk flexion and extension torques and powers between athletes and nonathletes. J Exerc Rehabil 2018; 14: 72–77.
73. Howard J, Granacher U, Behm DG. Trunk extensor fatigue decreases jump height similarly under stable and unstable conditions with experienced jumpers. European journal of applied physiology; 115. Epub ahead of print February 2015. DOI: 10.1007/s00421-014-3011-x.
74. Blache Y, Monteil K. Effects of spine flexion and erector spinae maximal force on vertical squat jump height: a computational simulation study. Sports Biomechanics 2015; 14: 81-94,.
75. Vanrenterghem J, Lees A, Clercq D. Effect of forward trunk inclination on joint power output in vertical jumping. Journal of strength and conditioning research; 22. Epub ahead of print May 2008. DOI: 10.1519/JSC.0b013e3181636c6c.
76. Blache Y, Monteil K. Influence of lumbar spine extension on vertical jump height during maximal squat jumping. Journal of sports sciences; 32. Epub ahead of print 2014. DOI: 10.1080/02640414.2013.845680.
77. Sasaki S, Nagano Y, Kaneko S, et al. The Relationship between Performance and Trunk Movement During Change of Direction. Journal of sports science & medicine 2011; 10: 112–8.

78. Behm DG, Sale DG. Intended rather than actual movement velocity determines velocity-specific training response. Journal of Applied Physiology 1993; 74: 359–368.
79. Stone MH, Moir G, Glaister M, et al. How much strength is necessary? Physical Therapy in Sport 2002; 3: 88–96.
80. Suchomel TJ, Nimphius S, Bellon CR, et al. The Importance of Muscular Strength: Training Considerations. Sports Med 2018; 48: 765–785.
81. Jandacka D, Uchytil J. Optimal load maximizes the mean mechanical power output during upper extremity exercise in highly trained soccer players. Journal of strength and conditioning research 2011; 25: 2764–2772.
82. LaPlaca DA, McCullick BA. National Football League Scouting Combine Tests Correlated to National Football League Player Performance. The Journal of Strength & Conditioning Research 2020; 34: 1317.
83. Alonso-Aubin DA, Chulvi-Medrano I, Cortell-Tormo JM, et al. Squat and Bench Press Force-Velocity Profiling in Male and Female Adolescent Rugby Players. The Journal of Strength & Conditioning Research 2021; 35: S44.
84. Hoff J. Training and testing physical capacities for elite soccer players. J Sports Sci 2005; 23: 573–582.
85. Hackney AC, Lane AR. Exercise and the Regulation of Endocrine Hormones. Prog Mol Biol Transl Sci 2015; 135: 293–311.
86. Cardoso LK. Comparison of 8-weeks of full versus split body resistance training on appetite and energy intake in non-obese untrained men | European Journal of Clinical Nutrition, https://www.nature.com/articles/s41430-024-01432-w (accessed 16 April 2024).
87. Bartolomei S, Hoffman JR, Stout JR, et al. Effect of Lower-Body Resistance Training on Upper-Body Strength Adaptation in Trained Men. Journal of Strength and Conditioning Research 2018; 32: 13–18.
88. Cook CJ, Kilduff LP, Beaven CM. Improving strength and power in trained athletes with 3 weeks of occlusion training. International journal of sports physiology and performance 2014; 9: 166–172.
89. Bagheri R, Rashidlamir A, Motevalli MS, et al. Effects of upper-body, lower-body, or combined resistance training on the ratio of follistatin and myostatin in middle-aged men. Eur J Appl Physiol 2019; 119: 1921–1931.
90. Keiner M, Kadlubowski B, Sander A, et al. Effects of 10 Months of Speed, Functional, and Traditional Strength Training on Strength, Linear Sprint, Change of Direction, and Jump Performance in Trained Adolescent Soccer Players. J Strength Cond Res 2022; 36: 2236–2246.
91. Spiering BA, Kraemer WJ, Vingren JL, et al. Elevated endogenous testosterone concentrations potentiate muscle androgen receptor responses to resistance exercise. The Journal of steroid biochemistry and molecular biology; 114. Epub ahead of print April 2009. DOI: 10.1016/j.jsbmb.2009.02.005.
92. Spillane M, Schwarz N, Willoughby DS. Upper-body resistance exercise augments vastus lateralis androgen receptor–DNA binding and canonical Wnt/β-catenin signaling compared to lower-body resistance exercise in resistance-trained men without an acute increase in serum testosterone. Steroids 2015; 98: 63–71.
93. Kraemer W, Patton J, Gordon S, et al. Compatibility of high-intensity strength and endurance training on hormonal and skeletal muscle adaptations. Journal of Applied Physiology 1995; 78: 976–989.