International Journal of Sports Science & Coaching

Original research

Sprint development practices in elite football code athletes

International Journal of Sports Science & Coaching
2022, Vol. 17(1) 95–113

DOI: 10.1177/17479541211019687
journals.sagepub.com/home/spo
SAGE

Ben Nicholson[1,2,3], Alex Dinsdale[1], Ben Jones[1,3,4,5,6], Omar Heyward[1,7] and Kevin Till[1,3]

Abstract

Despite the importance and complexity of developing sprint performance in football code athletes, there are limited studies exploring practitioners' practices to improves Sprinting. Therefore, this study aimed to describe and evaluate the practices used with elite football code athletes to develop sprint performance. Ninety subjects completed a survey comprised of four sections (coaching demographic, evaluation of training, organisation of training, and training protocols). Survey responses showed that 98% of practitioners monitor sprint performance, and 92% integrated monitoring strategies into sprint development programmes to inform training. All practitioners used combined training methods including specific (e.g., sprints with or without overload) and non-specific (e.g., strength training or plyometrics) methods targeting the underpinning determinants of sprint performance. Most practitioners reported prescribing 1–3 or 2–4 days $\cdot$ wk^{-1} for sprint development, both in-season and pre-season. Sprint development programmes were uncommon in the off-season. Most specific sprint training sessions were reportedly shorter in duration (5–15 and 15–30min) than non-specific sprint training methods (30–45 and >45min) irrespective of the season phases. Sprint development was integrated before and after sport-specific training, regularly using warm-ups and gym sessions. Specific training methods were also implemented in separate sessions. The specific content (e.g., exercise selection, training load prescription) was highly variable between practitioners. This study represents the first detailed survey (practices and justification) of sprint development practices (evaluation and organisation of training protocols) in football code cohorts. These findings present multiple methods of structuring, integrating and manipulating sprint training based on the training aims and the individual context.

Keywords

Running, speed, strength and conditioning, training

Introduction

The football codes (i.e., soccer, American football, Australian Rules football, rugby union, rugby league, rugby sevens, Gaelic football and futsal) are characterised by multi directional, intermittent bouts of high intensity running and sprinting (i.e., running at maximal or near-maximal velocities[1] interspersed between moderate and low-intensity activity.[2–5] Time-motion analyses have indicated that sprinting in the football codes involve athletes repeatedly performing short-sprints (~5–20 m distances and ~2–3 s duration) and less often sprints >20 m (e.g., 30–50 m), both initiating from static and more commonly moving start positions.[2–4] From a static start position, football code athletes typically require ~15–40m to achieve max velocity (v_{max})(~7–10 m $\cdot$ s^{-1} [6,7]), however, from a moving start

Reviewers: Dan Bishop (University of Lincoln, UK)
Jonathon Weakley (Australian Catholic University, Australia)
Warren Young (Federation University, Australia)

[1]Leeds Beckett University, Carnegie Applied Rugby Research (CARR) Centre, Carnegie School of Sport, Leeds, UK
[2]Yorkshire Carnegie Rugby Union Club, Leeds, UK
[3]Leeds Rhinos Rugby League Club, Leeds, UK
[4]England Performance Unit, The Rugby Football League, Leeds, UK
[5]School of Science and Technology, University of New England, Armidale, Australia
[6]Division of Exercise Science and Sports Medicine, Department of Human Biology, Faculty of Health Sciences, University of Cape Town and the Sports Science Institute of South Africa, Cape Town, South Africa
[7]Rugby Football Union, Twickenham, London, UK

Corresponding author:
Ben Nicholson, Carnegie Applied Rugby Research (CARR) Centre, Carnegie School of Sport, Leeds Beckett University, Headingley Campus, Leeds LS6 3QS, UK.
Email: B.t.nicholson@leedsbeckett.ac.uk

(i.e., walking or running), athletes may be exposed to $v_{\max}$ sprinting patterns when performing short-sprints.[2,8] Therefore, proficiency in each sequential phase of sprinting (e.g., early and late-stage acceleration; max velocity[9]) is essential for football code athletes.

Developing sprint performance (e.g., time for distance and instantaneous velocity) is considered a vital component of athletic performance within the football codes.[10] Linear sprint performance at various distances (e.g., 0–10, 0–20 and 0–40 m) has been shown to be a factor differentiating between playing standards,[11–13] as well as being associated with success in key attacking and defensive performance indicators across football codes (e.g., tries scored, line breaks, defenders beaten, tackles attempted and evaded[14,15]). This body of evidence emphasises the importance of sprint performance and its expression in game-specific outcomes for football performance and player development. Accordingly, football code athletes routinely undertake sprint development programmes to enhance performance.[16–19] The underpinning factors to sprint performance are consistent across sports.[9,20–22] Practitioners can target the determinants of performance, including (i) optimising the sequencing of stride length and frequency, (ii) enhancing the athlete's physical capacities relative to body mass (e.g., lower limb force-velocity-power and stiffness (ability to absorb the displacement of the leg and return high ground reaction forces[23])) and (iii) increasing the mechanical effectiveness of force application.[20,22,24–26] However, it is the content (e.g., exercise selection, training load prescription), the individual and the context (e.g., training and competition demands, sport and club infrastructure) that varies across and within sports.[16–18,27,28] Sprint development is commonly approached to stimulate favourable neural and morphological adaptations using either or both non-specific (i.e., strength, power, and plyometric training) and specific training methods which simulate the sprinting action (i.e., technical drills and sprints with various formats of overload).[20,22,24–26] This provides practitioners with multiple methods of developing sprint performance.[20,22,24–26] Hence, reviews of training studies have reported enhancing sprint performance concurrently alongside football code specific training.[20,22] However, such research often fails to reflect the contextual factors (e.g., timescales required to deliver outcomes, specific expertise, experience and resources) common in applied practice. Therefore, although all programmes should be based on current best evidence, professional reasoning is necessary to fill in the gaps and drive applied practice forward.[29]

Although multiple methods of enhancing sprint performance are available,[20,22] it has been reported to be the most difficult physical capacity to improve, especially within elite and experienced athletes.[30] Programmes are implemented within a complex training system constrained by logistical and contextual factors while simultaneously training multiple other (potentially) contrasting physical capacities (e.g., endurance) alongside the technical-tactical skills required for the football code.[16,19] Therefore, developing sprint performance is a challenge for all practitioners involved in the football codes. Despite this, there is limited available research examining football code athletes' sprint development training practices at the elite level.[16–18] Previous investigations use surveys related to the general strength and conditioning practices within rugby,[16,17,19,31] and American football.[18,32] Conducting a multi-football codes survey design would provide a more comprehensive overview of the contextual solutions to the performance problem (sprint performance development) than an individual sport alone. Thus, providing a more valuable resource to practitioners and researchers alike. Accordingly, investigating practitioner's practices for developing sprint performance is important to understand real-world methods for enhancing this physical capacity. Therefore, the purpose of this study was to describe and evaluate practitioner's practices and justifications for the organisation and evaluation of the training protocols for the development of sprint performance within football code athletes.

Method

Subjects

Ninety (n = 86 male; n = 4 female) practitioners participated. The standard of athletes that the practitioners worked with ranged from semi-elite to world-class ("semi-elite" n = 30, "competitive-elite" n = 30, "successful-elite" n = 24, "world-class elite" n = 6) based upon the definitions of Swann and colleagues.[33] No sex, age (both senior and youth teams included), nationality, qualifications, or experience restrictions were applied. The practitioners represented multiple-football codes (soccer n = 38, rugby union n = 25, rugby league n = 18, rugby sevens n = 3, Australian rules football n = 3, American football n = 2 and Gaelic football n = 1). Ethics approval was obtained, and all subjects were informed of the risks and benefits of the study before providing electronic informed consent form.

Study design

This exploratory study implemented an online self-administered survey titled "Speed development practices in football code teams" which was adapted from previous surveys and interviews of coaching practices.[16,18,34] The survey was modified to reflect the current practices, the rationale for decision making, and the practicalities of implementation in applied practice for developing sprinting performance in football code athletes. The survey was circulated internationally on a criterion-based sampling method of practitioners responsible for the physical preparation of football code athletes (practising between 2016–2019, e.g., strength and conditioning coach, athletic performance coach, sports scientist).

Procedures

The survey required practitioners to self-report a retrospective description of how they integrate sprinting development within their physical development practices. The survey consisted of four sections: coaching demographic, evaluation of training, organisation of training, and training protocols (Figure 1). Subjects were asked to give their most common or typical training values for each question. The survey instrument was developed, reviewed, and pilot tested, assessing for content and face validity by experienced practitioners in strength and conditioning coaching and applied research in athletes' physical development (>5 years experience).[35] Practitioners were recruited and provided access to the survey through professional networks via email and contact through social media platforms. Survey responses were collected and analysed using Qualtrics software (Qualtrics, Provo, USA) and Microsoft Excel. Only completed surveys were included.

Data analysis

The survey contained fixed-response and open-ended questions. Fixed responses questions were reported as means and standard deviations or frequencies and percentages of total responses where appropriate. Answers to open-ended questions were analysed according to the inductive and then deductive content analysis methods described by Elo and Kyngäs[36] to identify, analyse, and report common patterns (main categories) within the data. In cases where subjects provided a greater depth of information representing more than one concept, the responses contributed to more than one main category. Data rigour was enhanced as explored in Smith and McGannon[37] 1) through a process of critical dialogue and reflection, challenging and developing the interpretation of the content analysis with a critical friend (experienced in both strength and conditioning and applied research in practice), and 2) member reflection of the results.

Results

Practitioner demographic

Practitioner role. Ninety practitioners (n = 86 male, n = 4 female) of the 221 contacted (41%) responded to the survey. Thirty-two practitioners identified their roles as "*head*" ("*italicised text*" are direct quotations taken from the survey), "*lead*", "*senior*", "*director*" or "*manager*" of "*Sports Science*", "*performance*" or an "*athletic*" or "*physical*", "*performance*" or "*development*" roles, or "*S&C*", "*Athletic Performance*" or "*physical performance*" coaches.

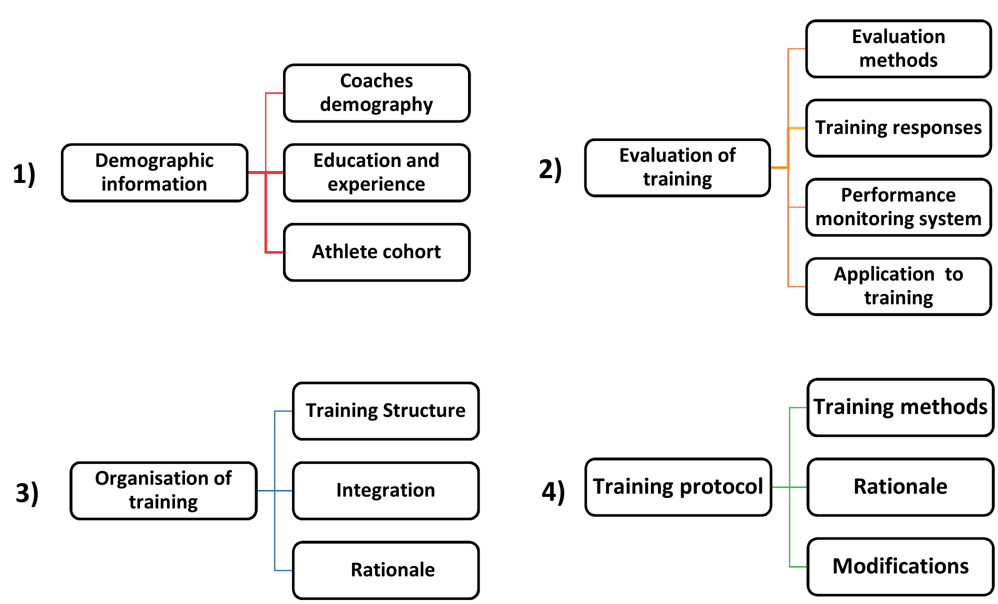

Figure 1. Thematic mind map of the survey.

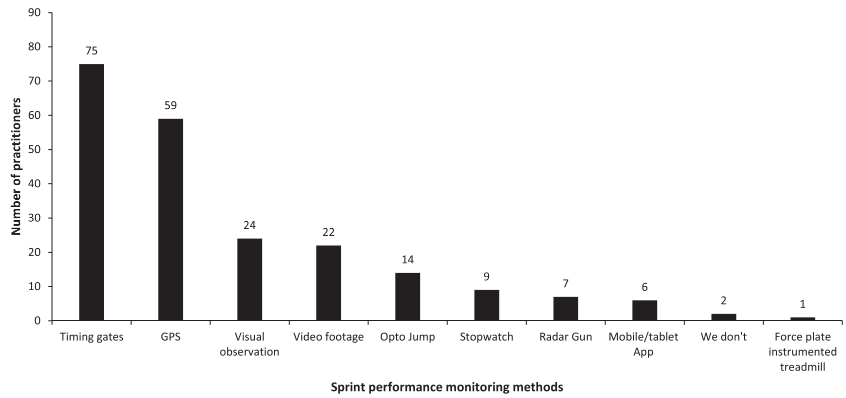

Figure 2. Sprint performance monitoring methods.

Table 1. Seasonal distance specific performance changes.

Sprint category	Pre-season	In-season	Off-season
A) Initial acceleration/ "first-step quickness" (0–5 m)	↑60 (67%)↓9 (10%)	↑56 (62%)↓16 (18%)	↑17 (19%) ↓27 (30%)
B) Short sprint/ acceleration performance (0–20 m)	↑65(72%)↓7 (8%)	↑66(73%)↓16 (18%)	↑17(19%)↓28(31%)
C) Longer sprint/ max velocity performance (0->20 m)	↑63(70%) ↓9 (10%)	↑67(74%) ↓18 (20%)	↑18 (20%) ↓ 29(32%)

Data presented as n, ↑ = Practitioner reported improvement ↓ = Practitioner reported a reduction in performance. Note: Several coaches did not respond to for specific distances at different time points indicating either being unsure and/or not testing for that distance outcome.

Fifty-eight practitioners identified as "*S&C*", "*performance*", "*athletic performance*", *or* "*athletic development*" coaches or "*sport scientist*" *roles*. Seven of which were "*assistant*" or "*intern*" roles. Ten roles involved dual roles such as "*sport scientist and strength and conditioning coach*" or "*rehab co-ordinator & sports scientist*" or academic roles (e.g., *"professor", "research fellow", "MRes", "PhD Student"* and *"lecturer" roles)*.

Education and experience. Collectively practitioners reported 7.4 ± 4.9 years of experience delivering strength and conditioning/speed training with athletes. The cohort included 26 certified strength and conditioning specialists (NSCA), 15 accredited strength and conditioning coaches (UKSCA), and 9 ASCA professional coach accreditation scheme (ASCA PCAS). Other physical preparation certifications held by the practitioners included *"USA"* and *"British weightlifting Level 1", "strength and conditioning coach certified (CSCCa)", "ASCA – not part of PCAS", "EXOS performance specialist", "EXOS strength sensei", "NSCA-certified personal trainer"* and "*Level 4 in strength and conditioning*". Seven coaches reported holding more than one certification. Twenty-eight practitioners did not hold accreditation to the relevant coaching professional bodies. The majority of practitioner's highest level of formal education was to a master's degree (n = 58).

Athlete cohort. Thirty-nine respondents reported working with senior athletes, and 51 with youth/academy players. Eighty-seven practitioners identified having worked with male athlete cohorts, whereas only 7 with female athletes.

Evaluation of sprint training

Evaluation methods. Ninety-eight percent of practitioners indicated that monitoring sprint performance was conducted with their athletes. Figure 2 shows the multiple monitoring methods used by practitioners. The practitioners reported monitoring variables such as "m*echanical profiles and peak velocity*", "*kinetic and kinematic variables*", "*time*" for a given distance (e.g., "*0, 5, 10, 20, 30 and 40 m*"), "*mean velocity, momentum*" and "*daily % of a players best* v_{max} *for the season*". As well as exposure *"% above* $7.0\,m{\cdot}s^{-1}$ *threshold*" and "*accelerations and decelerations (number of)*". The two practitioners not implementing monitoring methods reported financial or time constraints.

Training responses. Table 1 shows that most practitioners reported sprint performance improvements in pre-season and in-season and reductions over the off-season period regardless of the distance outcome.

Sprint monitoring. Table 2 depicts the details of the content analysis presenting the main categories, the total number of subjects and the select raw data that

Table 2. Sprint performance monitoring behaviour.

Main category	Count	Select raw data representing responses to this question
Periodic testing	60	*"Speeds are tested periodically", "at the beginning and end of each phase of the season". "The timing gates and radar gun are used as part of a testing battery across a season 3 times in pre-season, 2 in-season roughly every 5–12 weeks."*
Integrated into the weekly micro-cycle	44	*"Every day". "Every week". "Weekly". "GPS is used on a daily basis in training and competitive fixtures". "We use GPS to calculate max velocity on a daily basis". "Visual observation is used on a daily basis, particularly during the warm-up observing the movement patterns of individual players".*
During sprint training	5	*"Timing gates within sprint sessions or contrasted gym sessions. "These are across specific speed/acceleration/agility, weights sessions". "Video capture is performed during speed sessions if a coach is having to highlight parts of an athlete's technique".*
Return to play	4	*"RTP criteria with injured athletes as part as return-to-play protocols"*
Miscellaneous*	7	*"Depending on the fixture". "When the athletes are at their freshest". "Speeds are tested periodically with timing gates for formal testing". "GPS for a more on-field/applied setting". "radar gun used previously in research". "visual observation to get the coaches seeing if they are faster or not".*

*Answers that could not be associated with any of the broad identified main categories.

represent each main category for their performance monitoring system. Practitioners reported monitoring sprint performance using (a) periodic testing, (b) integrated into the weekly micro-cycle, (c) during sprint training sessions, (d) during return to play and (e) miscellaneous responses. The most common method reported was periodic testing (e.g., the start and end of training mesocycles or various time points across season time points [e.g., pre-season and in-season]).

Applications to training. Table 3 shows the reasons for monitoring sprint performance. This included (a) individualised training, (b) training validation, (c) identifying individual athlete requirements (d) data does not inform training prescription and (e) miscellaneous responses.

Organisation of training

Training structure. Practitioners reported a broad range of training frequencies (0 to 5d·wk^{-1}) and durations (0–5 to >45 min) of both specific and non-specific sprint training methods (Tables 4 and 5). Most practitioners prescribe 1–3 or 2–4d·wk^{-1}for both specific and non-specific training methods. For some practitioners, they varied training frequency and duration in line with phases of the season (pre-, in- and off-season). Pre-season represented the only period that >10% of practitioners reported prescribing non-specific training 3–5d·wk^{-1}. Both specific and non-specific training methods training prescription was uncommon in the off-season. The most frequently reported durations for the specific sprint training sessions were consistently shorter than non-specific sprint training methods (5–15 and 15–30 min vs. 30–45and >45 min) across each of the season phases (pre-, in- and off-season).

Table 6 shows the duration between specific and non-specific sprint training methods and technical/tactical training and/or competitive matches. Practitioners reported a range of durations from the same day to >48hrs. Most practitioners reported training both specific and non-specific on the same day as a technical/training session. Whereas, before a competitive match, more practitioners reported providing 48 or >48hrs recovery between specific and non-specific training and the match.

Integration of sprint training. All practitioners reported using both specific and non-specific training methods. The specific and non-specific training methods were integrated into the programme using multiple methods (Figures 3 and 4). Specific training integration methods included; during the warm-up, in separate speed sessions, integrated within the gym programme, at the start of technical/tactical sessions, manipulation of technical/tactical drills and at the end of technical/tactical sessions. Other methods included" *used in small doses where appropriate around the programme*", "*pre-activation sessions",* "*we have an hour to work with the players, the start of that hour will be dedicated to sprint mechanics etc.*". Non-specific methods included; integrated within the gym programme, during warm-ups, through manipulation of technical/tactical drills, at the start of a technical/tactical session, at the end of technical/tactical sessions. The other method reported was a "*special session for that*".

Table 3. How sprint performance monitoring informs training practices.

Main category	Count	Select raw data representing responses to this question
Individualised Training	40	*"Informs programming as part of an overall physical profiling perspective and is used in conjunction with force-velocity profiling for individual programming". "It informs individualised S&C programmes", "periodisation of speed exposure, drill selection", "and extra individual speed/accel development sessions". "This allows me to prescribe reps/distances needed to provide adequate stimulus", "prioritise and group individuals for speed development to ensure they are working to improve the desired variable". "Max Speed (via GPS) is used to prescribe a number of weekly sprints (>80% of Individual Max Speed Held for At Least A Second) to be attained during a week; number of sprints is both position and individual allocated)".*
Training validation	37	*"Track progress, manage volumes, determine threshold cut-offs", "the quality of my training", "if we are hitting enough top speed at training", "and progression of athlete development". "Measure if players have gotten faster, assess/validate training programme and prescription". "The GPS data provides an indicator of whether the required velocity has been reached". "New top speeds will change the velocity bands that an athlete operates within".*
Identifying individual requirements	36	*"A tool to assess the athlete's current level of skill proficiency. Allows me to profile athletes". "Players identified as faster or slower, relative to their position". "identify any specific areas of focus for improvement, i.e., a player's ability to accelerate, or maintain the ability to produce force over a longer sprint distance". "Force velocity profiles allow individual training needs to be identified". "FVP to inform primary work-on's for players (e.g., force or velocity deficit)". "Acceleration times (coupled with RSI/Various Jumps on ForceDecks/Strength Measures etc.) can be used to specify training direction and where physical qualities can be improved".*
Data does not inform training prescription	7	*"It doesn't. Data doesn't inform training prescription". "We just collect those data, without using them anyway". "Players will undergo speed training; however, the training is not individualised to that players specific needs e.g. acceleration or top speed".*
Miscellaneous*	9	*"Encourage competition and maximal effort". "GPS plus the demand of games". "It reinforces learning environment and objectives identified from mental model". "Live data feed and GPS report". "It gives us multiple tools to teach athletes using various learning styles". "Top speed, max accel and volume".*

*Answers that could not be associated with any of the broad identified main categories.

Table 4. Days per week "specific" and "non-specific" sprint training methods used during pre-season, in-season and off-season.

Training mode and phase	$0d \cdot wk^{-1}$	$1–3d \cdot wk^{-1}$	$2–4d \cdot wk^{-1}$	$3–5d \cdot wk^{-1}$	$>5d \cdot wk^{-1}$
Specific sprint training					
Pre-season	2 (2%)	53 (59%)	30 (33%)	4 (4%)	1 (1%)
In-season	2 (2%)	74 (82%)	11 (12%)	2 (2%)	1 (1%)
Off-season	31 (34%)	47 (52%)	9 (10%)	3 (3%)	0 (0%)
Non-specific sprint training					
Pre-season	3 (3%)	34 (38%)	35 (39%)	17 (19%)	1 (1%)
In-season	1 (1%)	52 (58%)	31 (34%)	5 (6%)	1 (1%)
Off-season	14 (15%)	45 (50%)	23 (36%)	6 (7%)	1 (1%)

Data presented as n (%). Values might not add up to exactly 100% due to rounding.

Rationale for sprint training structure. Table 7 shows the rationale for the structure of non-specific training methods. This included (a) logistics (e.g., fixture proximity, schedule, time, facilities), (b) fatigue management, (c) athlete's individual requirements, (d) training sequencing, (e) training efficacy, and (f) miscellaneous responses.

Training protocols

Content of training protocols. Tables 8 and 9 show the reported training protocols for sprint development. The specific methods reported included (a) sprint technique drills, (b) un-resisted sprinting, (c) resisted sprinting, (d) incline sprinting, (e) assisted sprinting, (f) weighted garments, (g) decline sprinting, (h) reduced

Table 5. Time typically spent on "specific" and "non-specific" sprint training methods within a training day during pre-season, in-season and off-season.

Training mode and phase	0–5 min	5–15 min	15–30 min	30–45 min	>45 min
Specific methods					
Pre-season	5 (6%)	28 (31%)	39 (43%)	11 (12%)	7 (8%)
In-season	6 (7%)	47 (52%)	29 (32%)	6 (7%)	2 (2%)
Off-season	28 (31%)	28 (31%)	17 (19%)	8 (9%)	5 (6%)
Non-specific methods					
Pre-season	3 (3%)	7 (8%)	16 (18%)	33 (37%)	30 (33%)
In-season	2 (2%)	10 (11%)	23 (26%)	32 (36%)	22 (24%)
Off-season	14 (16%)	9 (10%)	16 (18%)	23 (26%)	23 (26%)

Data presented as n (%). Values might not add up to exactly 100% due to rounding.

Table 6. The average time between "specific" and "non-specific" training methods and technical/tactical training and/or competitive matches.

	Same day	24 h	36 h	48 h	>48 h
Specific methods					
Time between technical/training session	80 (89%)	6 (7%)	1 (1%)	2 (2%)	1 (1%)
Time between a competitive match	5 (6%)	4 (4%)	13 (14%)	33 (37%)	35 (39%)
Non-specific methods					
Time between technical/training session	67 (74%)	13 (14%)	4 (4%)	3 (3%)	3 (3%)
Time between a competitive match	4 (4%)	15 (17%)	14 (15%)	31 (34%)	26 (29%)

Data presented as n (%). Values might not add up to exactly 100% due to rounding.

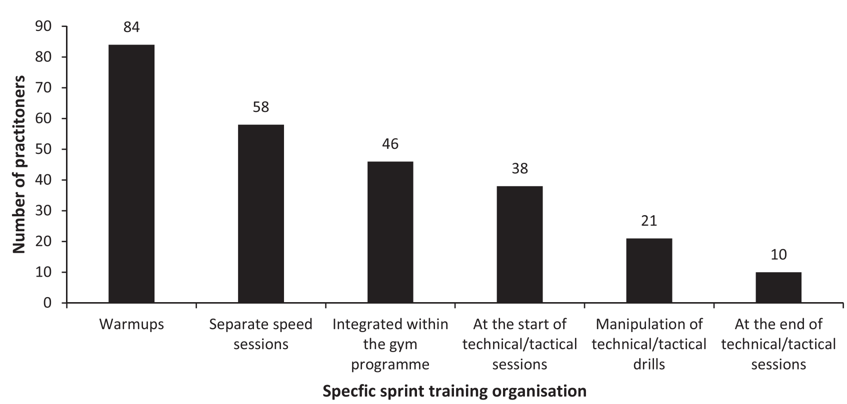

Figure 3. How "specific" sprint training is integrated into the whole training programme.

mass sprinting methods and (i) other responses (Table 8). Non-specific training methods reported included (a) plyometrics, (b) strength, (c) power, (d) strongman style, (e) flywheel training and (f) other responses (Table 9).

Rationale for training protocols. Table 10 shows the rationale for the exercise selection for developing sprinting performance. These included (a) individual requirements, (b) logistics, (c) training sequencing, (d) mechanical specificity, (e) sport-specific requirements, (f) evidence base and (g) miscellaneous responses.

Figure 5 shows that practitioners reported targeting multiple capacities using non-specific sprint training methods. These included the rate of force production, lower limb stiffness, vertical ground reaction forces, reduced ground contact times, force generation capabilities, force absorption capabilities, force transmission capabilities and inter- and intramuscular coordination, increased stride length and stride frequency. Other responses included, "*not sure*", "*force-velocity profile*" and "*technical efficiency*", "*increased contact times*" and "*joint kinematic*".

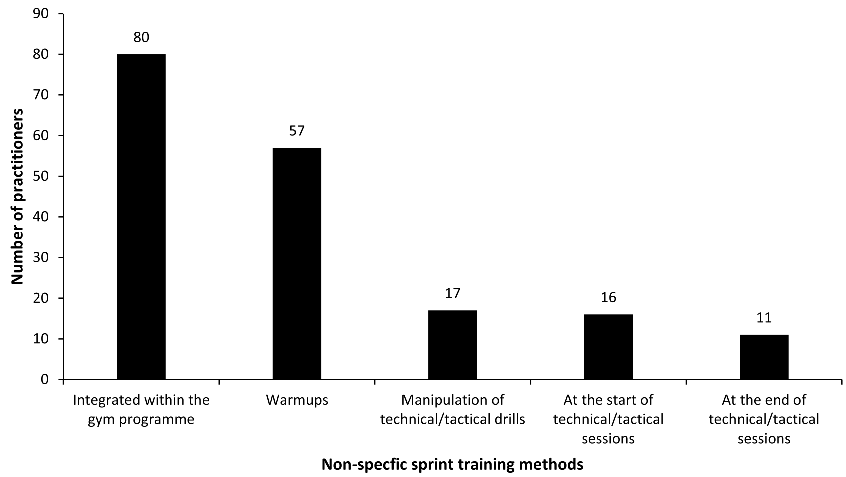

Figure 4. How "non-specific" sprint training is integrated into the whole training programme.

Table 7. The rationale for the structure of speed training.

Main category	Count	Select raw data representing responses to this question
Logistics	67	*"Mostly it is dictated by what you're allowed to do by the head coach". "The training demands are specific to the schedule week and the game itself". "The day of the match and the congestion of matches. We do not want to perform max effort sprinting unless we are 48-72 hrs prior to a match". "Based on time constraints with technical and tactical the primary focus". "We have limited exposure time with the players (3x45 mins), which restricts the opportunity to work elements which are not technical or tactical". "It is the most time effective for the training environment to develop and maintain speed". "The warm-up is the predominant time I can include speed tech work into our program". "It the point where I get the most time with the athletes". "Convenience".*
Fatigue management	29	*"Based around athlete fatigue levels, whether the athlete can reach a given level of their capacity". "We attempt to train in a way that we can reduce the amount of fatigue experienced by the athletes prior to specific speed training to attempt to maximise adaptions to training". "Try to get smaller doses of specific speed training due to fatigue and effecting technical practice". "Max sprinting - in warm-up, players need to be fresh". "We place speed training in the middle of our training week, at the further point from both the previous and next match".*
Individual requirements	20	*"Individual needs and previous exposures". "Athlete priorities. Athlete capability". "For older athletes - Power-based activities in strength sessions after football sessions due to intensity of strength sessions higher. Don't want them going into football fatigued and with a lot of muscle damage. Younger players lower intensity and movement competency emphasis - performed either pre or post-training". "The previous 3 weeks load, the present weeks load". "The volume of game my athletes performs, therefore we know how much stress through training can be applied and in what manner".*
Training sequencing	16	*"Tactical periodisation due to varying matchdays". "Periodised cycle". "My philosophy is that we build athletes physical qualities in a structured way then introduce chaos elements". "Using PAP techniques. Performing submaximal work followed by maximal sprint work".*
Training efficacy	14	*"By training this way, we get the best benefits/exposures for our athletes in our training environment". "Gym sessions provide the improvements in force production/power etc. Speed sessions involving technique drills and resisted access provide an opportunity of how best to apply this force to maximise speed and accel drills". "We observed that this is an effective strategy when combined with resistance training methods at the gym". "Attempt to maximise adaptions to training". "The use of micro-dosing is used to develop and maintain speed".*
Miscellaneous*	11	*"The players feedback". "In order to reduce the risk of injury". "Player safety". "Underpinned by training principles and theory". "Physiology". "Integration with technical model and demand". "Coach". "Experience and trial and error". "Warm-ups as a potentiation". "Buy in".*

*Answers that could not be associated with any of the broad identified main categories.

Table 8. Specific sprint training methods used to develop sprint performance.

Training mode	Count	Select raw data representing responses to this question
Sprint technique drills	80	*Exercises* "Wall sprints, build up acceleration sprints over incremented cones". "A & B-skips". "Scissor runs". "Speed dribbles". "Bosch Drills". "Dowel (overhead) sprints". "Arm pattern drills". "Wickets." *Loading* "2-4 sets of 10-30 m". "2-6 10-20 m efforts". "2-10 reps of 20-50 m". "15-minute block". "10-20minutes". "Anywhere from 100-200yd of drill volume".
Un-resisted sprinting	80	*Exercises* "Short to long complex - from various start positions - standing, falling, prone, supine". "Flying sprints". "Partner chase exercises". "Curved sprints". *Loading* "6-8 reps". "6-8 reps of 30-60 m". "3-12 reps of 5-50 m". "4 x 10 m, 4 x 20 m, 2 x 40 m". "flying 20 s with 20 m run in at 100% Vmax". "90-100% max effort". "100-300yd per session". "Up to 300 m of total volume".
Resisted sprinting	71	*Exercises* "Weighted sleds". "Band/partner resisted". "Band resisted marches, band resisted knee drives". "Run rocket". "Exer-Genie". "Depending on aim of session (force/velocity/power)". *Loading* "1-3 sets of 2-4 sprints of 15 m". "3-6 reps 10-20 m". "4- 8 efforts 20-40 m". "Low resistance up to 30 m; high resistance up to 15 m". "20%BM". "40-50% BM". "60-80% BW". "50% reduction of peak velocity". "Up to 200 m of sessional volume".
Incline sprinting	23	*Exercises* "Hills sessions". "Hill sprints". *Loading* "4-6 reps ~ 5-20 m". "2 x 4 x 15-20 m". "4-6 reps ~ 5-20 m". "5-10 reps of 5-15 m". "Slight 3-degree incline". "Up to 200 m of total sessional volume".
Assisted sprinting	18	*Exercises* "Overspeed training" Partner/band assisted". "Assisted marching". *Loading* "3-6reps 10-20 m". "6x30m". "4-6 reps 10 m towing, with 20 m burst out of it".
Weighted garments	12	*Exercises* "Skipping and other sprint specific speed drills". *Loading* [N/A]
Decline sprinting	9	*Exercises* "Downhill sprinting". *Loading* "4-6 repetitions 60-100 m". "3-5 reps at 110% Vmax".
Reduced mass sprinting	8	*Exercises* [N/A] *Loading* "If an athlete is injured or coming off long season". "Only in rehab scenarios volumes/intensities will programmed mostly by physios".
Other	4	*Exercises* "Contrast between resisted and un resisted sprint". "Band releases". "Submaximal tempo runs". "Woodway". *Loading* "At approximately 70% Vmax" "up to 600 m"

BM: body mass; Vmax: max velocity; [N/A]: no examples available.

Modifications to sprint training. Table 11 shows the practitioner's modifications to specific training methods to improve transfer to game performance. These included (a) task specificity, (b) integration of speed training into technical, tactical drills, (c) contextualised task awareness, (d) training sequencing, (e) individual requirements, (f) we do not, and (g) miscellaneous responses.

Table 12 shows the practitioner's modifications to non-specific training methods to improve sprint performance. These included (a) targeted training, (b) mechanical specificity, (c) training sequencing, (d) we

Table 9. Non-specific sprint training methods used to develop sprint performance.

Training mode	Count	Select raw data representing responses to this question
Plyometrics	87	*Exercises* *"Pogo variations". "Bounds, hurdle hops SL and DL, drop jumps, eccentric loaded box/drop jumps, SL drives". "Broad jump (uni and bi), box jumps (uni and bi)". "Band Assisted Jump Variants (Force-Velocity Curve Focus)". "Jump variations". "Low to high impact vertical/ lateral/horizontal". "Force production/ absorption (slow & fast stretch shortening cycle)".* *Loading* *"1-4 sets of 4-8 reps". "3-4 sets of 3-5". "Over speed". "Resisted". "Assisted". "Mixture of slow and fast SSC". "Weighted-vests as a resistance". "80-90 foot contacts". "Foot contacts around 100-120/session". "80-150 foot contacts".*
Strength training - resistance training using high-force or non-ballistic training.	86	*Exercises* *"A combination of various bilateral and unilateral, knee and hip dominant exercises". "Back Squat/Front Squat (Conventional/Box/Pause/Tempo/Chains/Bands)". "Dead lift variations". "Trapbar deadlift". "Rack pulls". "RDLs (Conventional, Single Leg, Split Stance)". "Hip thrusts (unilateral and bilateral)". "Step ups, isometric hamstring and adductor holds, hip thrust". "Nordic curl, Split squat, Bulgarian Split squat". Ecc/Iso/Con Focuses". "Accommodating resistance". "Hand supported". "Vertical and horizontal push and pull, rotational and anti-extension core stability".* *Loading* *"3-4 sets of 3-6 reps". "3-7 sets of 5-1 reps". "3-5 sets of 3-8 reps". "2-4 sets 2-5 reps". "80%+ of predicted 1 RM or working towards 1 to 2 repetitions in reserve". "80-100% 1rm".* *"<0.55-1.1m/s". "~ RIR= 1-3".*
Power Training - high-velocity or ballistic training, including Olympic lifting.	83	*Exercises* *"Weighted jumping". "VBT squatting/jumping". "Olympic weightlifting derivative". "KB swinging". "Lunge to step up exchanges". "MB overhead toss".* *Loading* *"3-4 sets of 4-5 reps". "3 to 5 sets x 1 to 3 reps". "3 sets - 4-6 reps". "30-60% predicted 1RM". "@ individualised average power loads". "Olympic variations @ 60-100%". "@>1.1m/s - >1.3 m/s". "~ RIR= 1-5"*
Strongman style training - compound movements of lifting and pulling unconventional objects.	18	*Exercises* *"Farmers walks, tyre flips, sledgehammers, sleds, med ball tosses". "Sled Pulling/Towing, Carries".* *Loading* *"3-8 reps, ~RIR= 2-5".*
Flywheel training	13	*Exercises* *"K-box squat, RDL, split squat, lateral lunge"* *Loading* *"3-4 sets of 5/8 reps with 2 in the tank"*
Other	1	*"Contrast Training - (simple contrasts/Triphasic Training/French Contrast Training)".*

Con: concentric; Bi: bilateral; DL: double leg; ecc: eccentric; iso: isometric; KB: Kettlebell; MB: medicine ball; RIR: reps in reserve; RM: repetition maximum; ssc: stretch shortening cycle; SL: single leg; Uni: unilateral; VBT: velocity-based training.

do not, (e) contextualised task awareness and (f) miscellaneous responses.

Discussion

This paper is the largest sample (n = 90) evaluating practitioner's practices and the first to identify the justifications for the organisation and evaluation of the training protocols for the development of sprint performance within football code athletes. In summary, the key findings were that practitioners 1) support sprint performance development programmes with monitoring strategies to inform training practices (i.e., individualised training, training validation, identifying individual athlete requirements) and 2) use a combination of specific and non-specific training methods to target the underpinning determinants of sprint performance (i.e., magnitude and orientation of force application). However, the content of training factors (e.g., training frequency, exercise selection, training load prescription) is highly variable across practitioners. This variability most often exists because of the logistics of the context (e.g., fixture proximity, schedule, time, facilities, stakeholder relationships) with the football codes.

Table 10. The rationale for the training prescription for developing sprinting performance.

Main category	Count	Select raw data representing responses to this question
Individual requirement	61	*"All depends on what the individual's needs are". "It is all based off a comprehensive athlete evaluation". "Weaknesses identified through data collected in other training modalities/screens i.e. GPS data, GymAware data, force plate tests, Nordbord tests, strength results". "Individual physical ability and whether the athlete requires specific areas of improvement (e.g., acceleration etc)". "Individual pathologies and readiness". "special needs (e.g. sore lower back when back squatting so will do leg press)". "the lifting ability and history (training and injury) of the athlete". "Force-velocity profiles of each individual ". "The needs of the athletes - Do we need to get stronger or move the load faster". "Depends on growth/maturation status. Also depends on movement proficiency shown by the players. Progression has to be earned". "Their mesocycle must have a blend of power and strength training to hit all part of the force-velocity curve". "The importance of improving sprinting speed relative to other physical qualities".*
Logistics	22	*"Constraints of the environment (space, equipment, time)". "Time constraints (if given short exposure to athletes will use exercises with most benefit ("bang for buck")". "Most of the sessions are in a team environment. We try to use exercises that are not too complex that a coach can manage coaching 18-22 athletes at once (sometimes up to 35)". "The rest of the training schedule". "Stage of training cycle currently in. Time of year (in season / season), Game turn around". "Equipment availability".*
Training sequencing	17	*"Progression of programme for athletes from inexperienced lifters to demonstrating competence". "General to specific progression based on joint ROM, movement velocities and ground contact time". "The physical component of the tactical session". "e.g., on Monday (strength day), I will emphasise on linear acceleration drills (wall drills, skips, various acceleration positions) with the main focus on developing horizontal forces, whereas on Thursday (speed day) I will incorporate more plyometrics for tolerance and development of vertical forces, related to max speed". "We try to include exercises across the entire force velocity spectrum and include isometric, eccentric, and concentric exercises at different times for different purposes".*
Mechanical specificity	11	*"Specificity". "We try to chase exercises that either match kinetically or kinematically to constituents of sprinting and use variability to improve skill retention". "Dynamical correspondence from a movement, functional or morphological perspective". "Specificity and Joint Angle Specificity to Running (i.e movement that will contribute to development of musculature involved in sprinting)". "Exercise that provide opportunity for high RFD triple extension exercises then high force exercises which overload musculature relating to sprinting".*
Sport-specific requirements	10	*"Demands of the sport ". "Playing style of the technical coach – e.g., if he has a high pressing philosophy then players need to be particularly strong at short explosive accelerations and decelerations, if he has a counter attacking philosophy, then max velocity is potentially very important". "The needs of the sport, say an athlete has to be both strong but fast". "Tactical position". "Position specificity". "E.g., position specific. What will make them better at their sport?".*
Evidence base	8	*"Experience/research/guidance". "Supporting research. Findings within literature". "Research-based practice and anecdotal experience".*
Miscellaneous*	5	*"Exercise prescription is not made at the pure linear speed level. Instead we program more holistically, whereby the planning of training is based on what methods will bring about increase in performance across multiple variables simultaneously i.e. Collisions, Speed, Robustness". "All types of movements and muscle groups are worked". "We include a range of exercise on the force-velocity spectrum, and H-V profiles. Some exercise will aim to develop high speed running mechanics, but typically, develop general neuro-muscular qualities". "Ensuring players are performing bilateral and unilateral exercises. Players are performing a range of different exercises which will produce the same outcome". "It wasn't my choice".*

*Answers that could not be associated with any of the broad identified main categories.

Evaluation of sprint training

Survey responses showed that 98% of respondents indicated that they evaluated sprint performance, presenting a higher frequency than previously reported (e.g., 77 ± 25% in rugby and American football[16–18,38]). Of which 92% reported using the data to inform training practices. The widespread use of evaluation methods suggests that practitioners consider evaluating sprint performance an important factor for athlete development

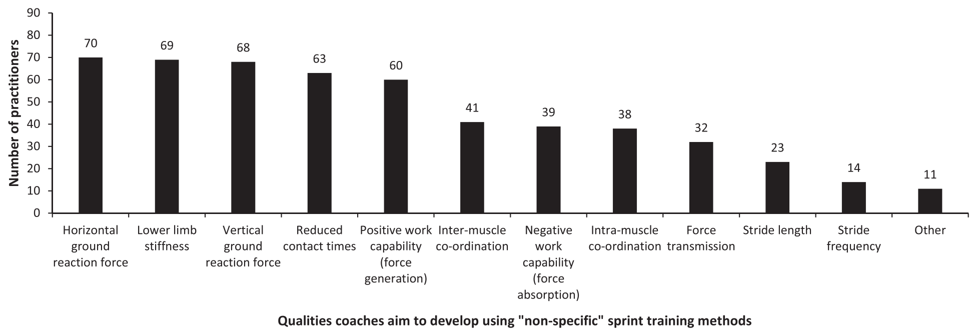

Figure 5. Qualities practitioners aim to develop using non-specific sprint training methods.

programmes within the football codes. This is consistent with the plethora of research investigating sprint exposures, changes in sprint outcomes and its associations with performance in both research and practice.[11–15,39] Most practitioners (54%) identified integrating sprinting monitoring within their regular training practices (e.g., weekly micro-cycle, during sprint training and return to play) in addition to periodic testing (e.g., pre-, mid-and end-of-season). The training literature base reports periodic sprint testing (e.g., every ∼6-8 weeks, in both the pre-and in-season phases) with limited studies implementing weekly monitoring, which may be a future direction for scientific research.[20,22] Integrated sprint monitoring may be beneficial to practitioners by providing a greater frequency of information to guide decision making.[27] However, it may also represent increased demands in the collection and the interpretation of the data. This highlights, the importance of strong collaboration within the performance team and systems in place to ease the burden of data collection and analysis.

Practitioners application of evaluating sprint performance has not previously been reported in the research. Current findings reported that practitioners identified individual requirements of athletes (40%), to provide individualised training (44%), alongside validating the training programme (41%) as important factors. Despite recording the data, 8% of practitioners reported not using it. Hence, profiling and individualisation of training, as well as measuring and producing quantifiable changes in sprint performance, are important to most practitioners. Future research should investigate practitioner's athlete profiling methods and the applications to practice to improve the understanding of how the data is informing individualised training.

Consistent with previous research, sprint performance evaluation is being achieved using velocity or time for distance measurements across a range of distances common in the football codes (e.g., "*0, 5, 10, 20, 30 and 40 m*"[16–18,38]). For practitioners to evaluate changes in sprint performance or inform training prescription effectively, they require valid and reliable testing equipment.[1] Numerous devices are capable of obtaining the required information,[20] hence, multiple methods were reported to measure sprint performance (e.g. timing gates, global positioning systems [GPS], video footage, radar guns and mobile applications). Only 2% of respondents report not testing sprint performance for logistical reasons (e.g., financial/time constraints). The widespread use of GPS (66%) and timing gates technology (83%) likely reflect their accessibility to practitioners and ease of use to collect reliable and valid data within applied environments.[1] Inconsistent with previous surveys,[16–19] practitioners reported measuring both "*mechanical profiles" and "kinetic and kinematic variables"*. Rather than simply understanding who is relatively faster or slower for a given distance, these methods allow practitioners to understand the limiting factors underpinning the athlete's sprint performance (e.g., maximum relative force production).[1,9,25,40] Using more comprehensive methods such as combined modelling of velocity-time curves with the assessment of kinematics (e.g., step length-frequency, contact-flight time interactions, segmental positions and motions) and stance kinetics (e.g., ground reaction force magnitude, orientation, and impulse) changes performed at more frequent intervals would enable practitioners to isolate and confirm a time course of adaptations and the underlying determinants to performance changes.[9,20,40]

Practitioners reported observing both positive and negative changes in all sprint performance outcomes (0–5, 0–20 and 0–>20 m) at each phase of training (pre-, in-, off-season). The distance outcomes used were selected to represent several components of sprints performance which are prevalent in the research literature, such as 1) initial acceleration/first-step quickness (0–5 m), 2) short sprint/acceleration performance (0–20 m) and 3) longer sprint/max velocity performance (0–>20 m).[6,7,20,22] Most practitioners reported improvements in sprint performance in pre- (≥70%) and in-season (≥62%). The pre- and in-season

Table 11. The rationale for modifications used to specific speed training methods to improve transfer to game performance.

Main category	Count	Select raw data representing responses to this question
Task specificity	74	*"Implementation of game scenarios, competition and implements". "Think about the specific demands of the game - e.g., in football the majority of sprints are not linear-oriented". "We use a lot of nonlinear maximal sprinting work, arcs, reaction work, chaotic work etc". "Introduce chaos to the activity. E.g. reactivity, defenders, decision making". "We also chase upper/lower body task separation, whereby the running gate has to be maintained while the upper body is reaching, restricted or occupied with another task". "Introduce sprint position seen within a game; type of starts used, flying starts as opposed to static, a walking start, turn and go etc". "We acknowledge the match demands and assess what characteristic has the greatest impact on performance (e.g., acceleration)". "Relatively short distances (up to 40 m) and brief recoveries (~1 min)".*
Integration of sprint training into technical, tactical drills	13	*"Speak to coaches to manipulate small sided games so athletes can work on game specific max velocity or acceleration/deceleration patterns". "Usually we introduce small-sided soccer games, with rules modification in order to favour sprint actions". "Slightly manipulate skills drills to express the speed". "Combining speed training into a rugby related activity/environment during certain periods".*
Contextualised task awareness	6	*"Contextualise". "By emphasising on technical points, with regards to the body-lean and aggressive foot contact on the ground during accelerations and/or quick and hard contacts during max speed running". "Coach the movement". "Also use rugby related ques & imagery".*
Training sequencing	5	*"Progress max velocity sprinting distance over training block. Introduce velocity variations within sprint training (flying sprints and sprint, glide, reaccelerate to full sprint). After an initial establishment of a technical model in the pre-season, we use a lot of nonlinear maximal sprinting work". "Speed development is sport specific and emphasizes postures and mechanics that transfer to game speed. This is built on a foundation of technical sprinting but is very important for us". "Connect it with evasive skills as soon as they develop reasonable sprinting technique".*
Individual requirements	4	*"Distances/loads specific to positional demands. Coaches may change session to focus on certain individuals". "I prefer to isolate the targeted quality and try to improve that". "Certain positions won't perform a lot of longer efforts so a lot of what they focus on will be shorter acceleration work as opposed to max velocity". "I think the biggest transfer to game performance is making sure they can sprint consistently at 90-95% of max velocity".*
We do not	6	*"Don't do anything". "Sport provides a large opportunity to express the movement skills of sprinting in specific context". "If our job is to increase top speed, then introducing too many external/game elements will prevent that". "We don't link speed sessions to football drills. It's separate". "Fake-sport-specialization has led to a trend toward making all locomotion activities multi-directional and agility-laden. Our Job is to make the athlete faster, the sport-specific work gets done in the sporting practice sessions". "Allow general qualities to self-emerge through working on positional tech/tact drill".*
Miscellaneous*	5	*"Adding incentives such as losers have to do this, or winner gets this". "Only really do linear speed but definitely should train more 'game speed' elements, players has to do everything at 100% (not always...) Intent". "Evidence-based". "incorporation of max velocity exposure, first step acceleration and competitive scenarios to ensure max effort".*

*Answers that could not be associated with any of the broad identified main categories.

changes are consistent with previous research presenting positive[20,22,41,42] and negative[20,22,41,43] responses. Therefore, when sprint development programmes are prescribed appropriately, practitioners appear to enhance sprint performance across the pre- and in-season training periods. Most practitioners did not respond to performance changes in the off-season period regardless of the distance outcome (≥51%), indicating either being unsure and/or not testing for that distance outcome. The majority of those who reported off-season changes reported reductions in performance for all distances. Several reasons have been

Table 12. The rationale for modifications used to non-specific training methods to improves print performance.

Main category	Count	Select raw data representing responses to this question
Targeted training	34	*"Monitor KPIs to make sure there is a positive transfer, utilise info from comprehensive evaluation to determine needs-analysis". "Addresses the physical characteristics that is relevant to the phase of sprinting, (Surfing the curve) but highlighting and overloading the curve at the point in which you want to improve that quality". "Feedback is also important (i.e. VBT)". "Try to target sprinting attractors". "Force velocity profile". "Do they need to be stronger or faster? E.g., player X imposes hip imbalance during a barbell hip thrust (right hip dominant)".*
Mechanical specificity	21	*"Exercises that match body positions used during sprint performance gait". "Adjust movements to more sport specific joint angles (half squat, split squats for hip separation)". "Emphasis on the concentric phase being as fast as possible, manipulation of time under tension in muscle action, including unilateral movements, some plyometrics with shorter ground contacts, matching exercise with mechanical similarity to sprinting (foot stiffness, hip lock etc)".*
Training sequencing	17	*"Complex/contrast using PAP". "I put sometime I specific exercise in a contrast method". "Combinations of movement patterns in the gym for PAP effects such as triple extension exercises (pulls) into short sprint accelerations". "Focus on developing the foundations in athletes before beginning to use higher loads/reduced volume and explosive movements (contrast) to train athletes to get stronger and more explosive (PAP somewhat)". "Once strong enough just get sprinting". "Blend/splice the session". "Periodisation of training to allow realisation of strength and power into speed. With younger athletes ive found generally that there's a greater transfer of general strength qualities to sprint performance. In older athletes spending longer in specific phases provides greater transfer to sprint performance".*
We don't	6	*"Don't do anything", "aim is more towards athletic development rather than transfer to sprint performance in isolation". "We don't, this is achieve through the use of general training".*
contextualised task awareness	7	*"Contextualise the session". "Ensure the athletes understand the purpose of the exercise and ensure the exercise itself compliments the demands of sprinting". "Conscious tasks in my dynamic situation".*
Miscellaneous*	10	*"Technique>load, Quality>quantity. Intent, Evidence-based". "Differs from each player. Many have different training backgrounds and history's". "Working within repetition ranges which the literature has demonstrated as having a positive influence on sprint performance".*

*Answers that could not be associated with any of the broad identified main categories.

suggested for lack of improvements in sprint performance, including methodological considerations (e.g., equipment and environmental factors), residual fatigue, the accumulation of conflicting training volume and interference effects, providing insufficient stimulus, individual requirements and adaption kinetics not presenting changes at that testing timepoint.[1,20,22,41] Practitioners should be aware of this within their planning and delivery of training within football code athletes. Further research is required to explore the gaps in understanding seasonal changes in sprint performance and underpinning mechanisms.

Organisation of training

Consistent with previous research,[16–19] all practitioners undertake sprint training within their programmes. All practitioners reported providing a combined approach using both specific and non-specific training methods consistent with previous coaches in rugby and American Football[16–19] and recent meta-analysis findings for short and medium to long-distance sprints.[20,22] Combined training methods are likely the most effective as they enable practitioners to provide stimuli to develop neurological and morphological adaptations associated with enhancing both the lower limb's physical capacities and the athlete's mechanical efficiency concurrently.[20,22] These results indicate that practitioners consider these training methods important for developing sprint performance alongside other physical capacities required for the football codes. However, the challenge with combined training is the organisation of the frequency, volume, intensity and order of training methods specific to the individual's requirements within the constraints of the context to elicit an enhanced performance.[20,22,26,30]

Most practitioners reported prescribing 1–3 or 2–4d·wk^{-1} for both specific (pre- and in-season =>92%) and non-specific (pre- and in-season =

>77%) training methods. Previous surveys reported that the most common training frequencies reported were 1–2d·wk^{-1} for specific methods[38] and 3–4 d·wk^{-1} for non-specific training methods.[16,17,38] These training frequencies align with the ranges prevalent in the training literature, presenting an evidence base for effective training programme design.[20,22] Despite the consistency in the training frequency, there are variable weekly practices across both pre- and in-season periods ranging from a minimum of 1–2 to at most 3–4d·wk^{-1}. The variation in training frequency likely reflects the weekly and seasonal fluctuations in training volumes and intensity, the turn around between fixtures and the individual requirements of athletes.[19,20,22] Novel findings included reporting the duration of both specific and non-specific training methods. Specific sprint training sessions (5–15 and 15–30 mins) were consistently shorter than non-specific training methods (30–45 and 45–60 mins). Considering the requirement of full recovery between each sprint, to achieve maximal intensity when sprinting and the volumes required to enhance sprint performance (100–300 m of acceleration vs. 50–150m of $v_{\max}$ phase running[25]), the prescription of shorter durations (5–15 min) may represent sub optimal volume or intensity to illicit favourable adaptations.[25] The reduced time provided for specific training potentially suggests a lower prioritisation of specific speed training methodologies. This may be because of the multiple physical capacities needed within the football codes (e.g., strength, power, endurance). As with previous surveys,[16–19] the practitioners reported variation in the organisation of their training protocols and seasonal variations in training structure.

Consistent with previous literature, the sprint training methods were integrated into the training system through various formats. Although variation was present between specific and non-specific training methods, sprint development involved training implemented in warm-ups (specific = 93%; non-specific = 63%), within the gym programme (specific = 51%; non-specific = 89%), pre (specific = 42%; non-specific = 18%) and post (specific = 11%; non-specific = 12%) technical/tactical sessions, and manipulation of technical/tactical drills (specific = 23%; non-specific = 19%). The high prevalence of specific sprint training in the gym programmes may reflect accessibility to specialist facilities (e.g., artificial turf tracks) or implementation of various formats of "*sprint technique drills*" which can be performed stationary or over a small area. The novel finding presented that practitioners were also performing individual sessions for specific training methods (64%). The main reason reported for the training structure was due to logistics (e.g., fixture proximity, schedule, time, facilities; 74%). In practice, limited time is available for strength and conditioning sessions.[19,30] When planning, training practitioners should consider the time-cost of training from the overall sport skill development and the potential implications of residual fatigue on the quality, risk and rewards of training considering the organisation of training.[20,22,44] Practitioners also reported athletes' structuring training based on individual requirements (22%), training sequencing (18%) and training efficacy (16%). Therefore, practitioners require simple, effective training methods, that address the individual needs within the sequencing of training and within limited resources (e.g., time, equipment, non-specialist facilities) while concurrently enhancing several locomotive-specific actions. These methods should be underpinned with an evidence base to understand the potential acute and chronic effects on performance while achieving the greatest gains in performance for a given amount of work effort.

Practitioners reported structuring training for fatigue management (32%). Both specific and non-specific training methods result in acute neuromuscular fatigue.[25] This is evident in that practitioners reported variation between the organisation of training concerning proximities to fixtures, the frequency and duration of training. Most practitioners reported training both "specific" (89%) and "non-specific" (74%) training on the same day as a technical/training session. Whereas, before a competitive match, more practitioners reported providing 48 or >48 hrs recovery between specific (37 and 39% respectively) and non-specific training (34 and 29% respectively) and the match. As a result of non-specific and specific training methods, athletes develop fatigue (e.g. muscle soreness, reductions in substrate availability) and require recovery between sessions and competition to maximise training and playing intensity capabilities.[20,25] Consequently, many practitioners appear to accept the residual fatigue from training; however, they attempt to minimise training near fixtures providing 48 hrs recovery before games.

Training protocols

Sprinting is not solely a physical capacity, but a fundamental skill based on coordination and precision.[9,45] Hence, the magnitude and orientation of ground reaction forces that can be achieved within the mechanical limitations of sprinting (task constraints; e.g., reduced stance time to apply force at greater velocities) are identified as the largest determinants of maximal running speed in humans.[9,45] Thus, the interplay of technical skill and physical capacities provides practitioners with numerous methods to improve sprinting ability alongside the underpinning adaptations (neurological and morphological) responsible for the mechanical determinants of sprinting.[9,20,22,25] Consistent with previous findings, performance development is being approached using combined methods of specific and non-specific training methods, targeting the underpinning determinants of sprint performance.[16–18,38] However, the content (i.e., exercise selection, training load prescription) varied across practitioners, as previously reported in football cohorts (rugby and American football) and even in elite sprinters.[16,17,46]

The rationale for the sprint development training prescription most frequently was the individual's requirements (68%). Although less common, practitioners reported sport-specific requirements (11%) contributing to training prescription such as positional differences, which have previously identified differences between performance standard in football code athletes.[11–13] Research has shown that training programmes can provide targeted stimuli to the underpinning mechanical components of the neuromuscular system that determine sprint performance (e.g., force-velocity-power outputs and relationships) as well as the mechanical effectiveness of the athlete (orientation of forces applied into the ground as velocity increases).[20,22,26] Consistent with reviews of the training literature[20,22,26] practitioners reported targeting favourable adaptations for sprint performance. These were represented as improved physical and technical outputs either individually or in combination, i.e., increases in impulse (greater generation of ground reaction forces in shorter ground contacts, >70%), stiffness (43%), force transmission (36%) and inter- (46%) and intra-muscular coordination (38%). These were reported in conjunction with improving stride parameters, such as length (26%) and frequency (16%). The practitioners also reported logistics (24%), training sequencing (19%), mechanical specificity (12%) and evidence base (9%) as a rationale for their training prescription. Thus, presenting several factors that may contribute to the variation in training prescription and their reported effectiveness.

Practitioners rationale for training prescription-varied depending on their perceived transfer to sprint performance, resulting in several variations in specific and non-specific training methods. Practitioners reported using variations of these movements in which they felt best enhanced sprinting performance based on mechanical specificity (e.g., the amplitude and direction of the movement, the accentuated region of the force production, the dynamics of the effort, the rate and time of maximum force production, and the regime of muscular work[9,47]). The current evidence base suggests that there are multiple methods of enhancing sprint performance; however, no specific exercise or programme is considered the most effective for all athletes.[20,22] Instead, practitioners have multiple solutions to approach targeting the underpinning capacities, and skills and practitioners should aim to provide appropriate training prescription for the athlete relevant to the context at that time point.

Practitioner's reported modifications to both specific and non-specific training methods to improve transfer to game performance. Specific methods modifications included task specificity (e.g., game-specific distances sprints with non-linear and task constraints; (82%)) and integration of sprint training into technical, tactical drills (e.g., rules modification to favour sprint actions in-game scenarios (14%)). Less common were contextualised task awareness (7%), training sequencing (e.g., manipulating the order of training to maximise the stimulus (6%)) and individual requirements (4%), targeting players specific needs. Non-specific training methods modifications included targeted training (38%), mechanical specificity (23%), training sequencing (19%) and contextualised task awareness (8%). These factors provide several potential options for practitioners to modify training prescription for increased transfer to performance. Further research is required to assess the efficacy of these methods.

Football codes performance is a multifaceted and complex phenomenon that requires the combination of physical, perceptive, cognitive, technical, and tactical capabilities.[48] Practitioners, therefore, are concurrently training multiple capacities simultaneously to develop general athleticism (e.g., multiplanar movement skills) and the underpinning capacities (e.g., lower limb strength, power and stiffness).[16,17,19] Although less frequent, practitioners report not modifying specific (7%) or non-specific (7%) training methods, potentially reflecting contrasting training philosophies on the specificity requirements of training methods. Most practitioners reported trying to maximise task specificity, attempting to replicate "*game-specific*" patterns (e.g., non-linear, varied distances/starting formats and contextual scenarios[3,48]). In contrast, several practitioners suggest this is "*hyper sports specialisation*" inferring contextualisation as potentially detrimental to developing sprint capacities and instead "*allow general qualities to self-emerge through working on positional tech/tact drill*" and focus on providing maximal intensity of the training exposures using traditional linear sprint training. Despite a clear continuum, comprehensive athletic development would involve combining both approaches. Therefore, sprint development needs to be context-specific, and professional reasoning is necessary to fill in the gaps in the literature for the relative contribution of each domain (general vs specialised).[27,48]

Limitations

Whist this study represents the largest and most comprehensive evaluation of the sprint development practices within elite football codes, limitations exist. First, despite the criterion-based sampling method, the completed survey data may represent non-response and self-selection bias, potentially missing practitioners whose non-response is related to the propensity towards involvement in sprint development.[49] Secondly, a multi-football code approach was used to provide a "big picture" overview of sprint development practices. However, given the differences in competition structure and support levels around different competition levels, age groups and sports, this likely reflects some of the variations in training organisation based on individual contextual demands (i.e., logistical constraints). It is important to note although this cohort includes responses from practitioners working with "elite" football code athletes, the playing standard of the athlete is not a measure of the quality of the practitioner's capability or competency. Therefore, these responses should not be considered best practice; instead, as a source of the collective ideas from practitioners for comparison, critique and potentially application into practice.

Practical implications

1. Where possible, practitioners should use valid and reliable monitoring methods that can be integrated into the training process to provide frequent, actionable information to guide their decision making.
2. By supporting monitoring with more comprehensive methods such as combined modelling of velocity-time curves with the assessment of kinematics (e.g., step length-frequency, contact-flight time interactions, segmental positions and motions) and stance kinetics (e.g., force magnitude, orientation, ratio, and impulse) objective data can expand on measures of time/velocity to identify limiting factors for sprint performance to guide training.
3. Although variable, there appear to be several effective methods of appropriately structuring and prescribing combined approaches of non-specific and specific sprint performance development strategies across a season. These methods involve increasing either or both the magnitude and the orientation of force an athlete can generate and express in the sprinting action.
4. Practitioners should consider the order of their training and the potential implications of residual fatigue on the quality, risk and rewards of sprint development.
5. Applied sprint development involves adapting to the constraints of the environment and the athlete's requirements (s). Therefore, a one size fits all approach to sprint development is not applicable; instead, training strategies need to be context-specific.

Conclusion

These findings present multiple methods of structuring, integrating and manipulating sprint training based on the aims and the individual requirements of athletes, and the constraints of the context. Most practitioners support sprint development programmes with integrated monitoring strategies to inform training and implement combined training methods to target and enhance the underpinning determinants of sprint performance, including several formats and content of both specific and non-specific methods (e.g., exercise selection, training load prescription and distribution of specific and non-specific training). The variation in training content between practitioners (e.g., exercise selection, training load prescription) and training effectiveness (i.e., performance changes) presents that despite the apparent multiple effective sprint development methods, effective training likely represents a narrower range of practices than those reported. During the in-season and pre-season period, most practitioners reported prescribing 1–3 or 2–4 $d \cdot wk^{-1}$ for sprint development. However, sprint development programmes were uncommon in the off-season. Shorter durations were more frequently prescribed for specific training methods (5–15 and 15–30min) compared to non-specific (30-45 and >45min) irrespective of the phase of the season. Sprint development was integrated both before and after sport-specific training, regularly using warm-ups and gym sessions. Separate sessions were frequently reported for specific training methods. Practitioners now have a source of data describing sprint performance development practices across the elite football code athletes, which can be used as a centralised resource to inform, challenge and develop current practices. Future researchers could use the presented data to design experimental protocols examining the effect of existing or new sprint performance development practices in football code athletes.

Acknowledgements

The authors would like to thank all individuals who participated in the study.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iDs

Ben Nicholson https://orcid.org/0000-0003-1664-6386
Omar Heyward https://orcid.org/0000-0002-7390-6511

References

1. Haugen T and Buchheit M. Sprint running performance monitoring: methodological and practical considerations. *Sports Med* 2016; 46: 641–656.
2. Duthie GM, Pyne DB, Marsh DJ, et al. Sprint patterns in rugby union players during competition. *J Strength Cond Res* 2006; 20: 208–214.
3. Gabbett TG. Sprinting patterns of national rugby league competition. *J Strength Cond Res* 2012; 26: 121–130.
4. Di Salvo V, Baron R, González-Haro C, et al. Sprinting analysis of elite soccer players during European Champions League and UEFA cup matches. *J Sports Sci* 2010; 28: 1489–1494.
5. Whitehead S, Till K, Weaving D, et al. The use of microtechnology to quantify the peak match demands of the football codes: a systematic review. *Sports Med* 2018; 48: 2549–2575.
6. Barr MJ, Sheppard JM and Newton RU. Sprinting kinematics of elite rugby players. *J Aust Strength Cond* 2013; 21: 14–20.
7. Clark KP, Rieger RH, Bruno RF, et al. The national football league combine 40-yd dash: how important is maximum velocity? *J Strength Cond Res* 2019; 33: 1542–1550.
8. Young WB, Duthie GM, James LP, et al. Gradual vs. maximal acceleration: their influence on the prescription of maximal speed sprinting in team sport athletes. *Sports* 2018; 6: 66.
9. Moir GL, Brimmer SM, Snyder BW, et al. Mechanical limitations to sprinting and biomechanical solutions: a constraints-led framework for the incorporation of resistance training to develop sprinting speed. *Strength Cond J* 2018; 40: 47–67.
10. Bishop DJ and Girard O. Determinants of team-sport performance: implications for altitude training by team-sport athletes. *Br J Sports Med* 2013; 47: i17–i21.
11. Till K, Scantlebury S and Jones B. Anthropometric and physical qualities of elite male youth rugby league players. *Sports Med* 2017; 47: 2171–2186.
12. Delaney JA, Olson TM and Morin J-B. Sprint acceleration mechanical profiling for the NFL draft. *Sports Perform Sci Rep* 2018; 27: 1–3.
13. Baumgart C, Freiwald J and Hoppe M. Sprint mechanical properties of female and different aged male top-level German soccer players. *Sports* 2018; 6: 161.
14. Ross A, Gill N, Cronin J, et al. The relationship between physical characteristics and match performance in rugby sevens. *Eur J Sport Sci* 2015; 15: 565–571.
15. Gabbett TJ, Jenkins DG and Abernethy B. Relationships between physiological, anthropometric, and skill qualities and playing performance in professional rugby league players. *J Sports Sci* 2011; 29: 1655–1664.
16. Jones TW, Smith A, Macnaughton LS, et al. Strength and conditioning and concurrent training practices in elite rugby union. *J Strength Cond Res* 2016; 30: 3354–3366.
17. Jones TW, Smith A, Macnaughton LS, et al. Variances in strength and conditioning practice in elite rugby union between the Northern and Southern hemispheres. *J Strength Cond Res* 2017; 31: 3358–3371.
18. Ebben WP and Blackard DO. Strength and conditioning practices of national football league strength and conditioning coaches. *J Strength Cond Res* 2001; 15: 48–58.
19. Heyward O, Nicholson B, Emmonds S, et al. Physical preparation practices in female rugby. *Front Sports Act Living* 2020; 2: 1–14.
20. Nicholson B, Dinsdale A, Jones B, et al. The training of short distance sprint performance in football code athletes: a systematic review and meta-analysis. *Sports Med* 2020; 40: 1–29.
21. Colyer SL, Nagahara R, Takai Y, et al. How sprinters accelerate beyond the velocity Plateau of soccer players: waveform analysis of ground reaction forces. *Scand J Med Sci Sports* 2018; 28: 2527–2535.
22. Nicholson B, Dinsdale A, Jones B, et al. The training of medium-long distance sprint performance in football code athletes: a systematic review and Meta-analysis. *Sports Med* 2020.
23. Morin J-B, Dalleau G, Kyröläinen H, et al. A simple method for measuring stiffness during running. *J Appl Biomech* 2005; 21: 167–180.
24. Bezodis IN, Kerwin DG, Cooper S-M, et al. Sprint running performance and technique changes in athletes during periodized training: an elite training group case study. *Int J Sports Physiol Perform* 2018; 13: 755–762.
25. Haugen T, Seiler S, Sandbakk O, et al. The training and development of elite sprint performance: an integration of scientific and best practice literature. *Sports Med – Open* 2019; 5: 1–16.
26. Hicks D, Schuster J, Samozino P, et al. Improving mechanical effectiveness during sprint acceleration: practical recommendations and guidelines. *Strength Cond J* 2020; 42: 45–62.
27. Till K, Muir B, Abraham A, et al. A framework for decision-making within strength and conditioning coaching. *Strength Cond J* 2019; 41: 14–26.
28. Haugen TA, Breitschädel F and Seiler S. Sprint mechanical variables in elite athletes: are force-velocity profiles sport specific or individual? *Plos One* 2019; 14: e0215551.
29. English KL, Amonette WE, Graham M, et al. What is "Evidence-Based" strength and conditioning? *Strength Cond J* 2012; 34: 19–24.
30. Haugen T. Sprint conditioning of elite soccer players: worth the effort or lets just buy faster players? *Sport Perform Sci Rep* 2017; 1: 1–2.
31. Robinson B, Pote L and Christie C. Strength and conditioning practices of high school rugby coaches: a South African context. *S Afr J Sci* 2019; 115: 1–6.

32. Fitzgerald CF and Jensen RL. A comparison of the national football league coaches strength and conditioning practices 1997–1998 to 2018. *ISBS Proc Arch* 2019; 37: 73.
33. Swann C, Moran A and Piggott D. Defining elite athletes: Issues in the study of expert performance in sport psychology. *Psychol Sport Exerc* 2015; 16: 3–14.
34. Bolger R, Lyons M, Harrison AJ, et al. Coaching sprinting: expert coaches' perception of resistance-based training. *Int J Sports Sci Coach* 2016; 11: 746–754.
35. Bolarinwa OA. Principles and methods of validity and reliability testing of questionnaires used in social and health science researches. *Niger Postgrad Med J* 2015; 22: 195.
36. Elo S and Kyngäs H. The qualitative content analysis process. *J Adv Nurs* 2008; 62: 107–115.
37. Smith B and McGannon KR. Developing rigor in qualitative research: problems and opportunities within sport and exercise psychology. *Int Rev Sport Exerc Psychol* 2018; 11: 101–121.
38. Heyward O, Nicholson B, Emmonds S, et al. Physical preparation in female rugby codes: an investigation of current practices. *Front Sports Act Living* 2020; 2: 1–14.
39. Cunningham DJ, Shearer DA, Drawer S, et al. Relationships between physical qualities and key performance indicators during match-play in senior international rugby union players. *Plos One* 2018; 13: e0202811.
40. Morin J-B and Samozino P. Interpreting power-force-velocity profiles for individualized and specific training. *Int J Sports Physiol Perform* 2016; 11: 267–272.
41. Haugen TA. Soccer seasonal variations in sprint mechanical properties and vertical jump performance. *Kinesiology* 2018; 50: 102–108.
42. Weakley J, Till K, Sampson J, et al. The effects of augmented feedback on sprint, jump, and strength adaptations in rugby union players following a four week training programme. *Int J Sports Physiol Perform* 2019; 14: 1205–1221.
43. Jimenez-Reyes P, García Ramos A, Montilla JA, et al. Seasonal changes in the sprint acceleration force-velocity profile of elite male soccer players. *J Strength Cond Res* 2020; 1: 1–10.
44. Edouard P, Mendiguchia J, Lahti J, et al. Sprint acceleration mechanics in fatigue conditions: compensatory role of gluteal muscles in horizontal force production and potential protection of hamstring muscles. *Front Physiol* 2018; 9: 1706.
45. Morin J-B, Edouard P and Samozino P. Technical ability of force application as a determinant factor of sprint performance. *Med Sci Sports Exerc* 2011; 43: 1680–1688.
46. Bolger R, Lyons M, Harrison AJ, et al. Sprinting performance and resistance-based training interventions: a systematic review. *J Strength Cond Res* 2015; 29: 1146–1156.
47. Siff M and Verkhoshansky Y. *Supertraining: special strength training for sporting excellence: a textbook on the biomechanics and physiology of strength conditioning for sport*. Johannesburg, South Africa: The School of Mechanical Engineering, 1993.
48. Jeffreys I, Huggins S and Davies N. Delivering a game speed-focused speed and agility development program in an English premier league soccer academy. *Strength Cond J* 2018; 40: 23–32.
49. Cheung KL, Peter M, Smit C, et al. The impact of non-response bias due to sampling in public health studies: a comparison of voluntary versus mandatory recruitment in a Dutch national survey on adolescent health. *BMC Public Health* 2017; 17: 10.