STRENGTH AND CONDITIONING AND CONCURRENT TRAINING PRACTICES IN ELITE RUGBY UNION

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ABSTRACT

There is limited published research on strength and conditioning (S&C) practices in elite Rugby Union (RU). Information regarding testing batteries and programme design would provide valuable information to both applied practitioners and researchers investigating the influence of training interventions or pre performance strategies. The aim of this study was to detail the current practices of S&C coaches and Sport Scientists working in RU. A questionnaire was developed that comprised 7 sections; personal details, physical testing, strength and power development, concurrent training, flexibility development, unique aspects of the programme and any further relevant information regarding prescribed training programmes. Forty-three (41 male, 2 female; 33.1 ± 5.3y) of 52 (83%) coaches responded to the questionnaire. The majority of practitioners worked with international level and/or professional RU athletes. All respondents believed strength training benefits RU performance and reported their athletes regularly performed strength training. The clean and back squat were rated the most important prescribed exercises. Forty-one (95%) respondents reported prescribing plyometric exercises and 38 (88%) indicated periodisation strategies were employed. Forty-two (98%) practitioners reported conducting physical testing, with body composition being the most commonly tested phenotype. Thirty-three (77%) practitioners indicated that the potential muted strength development associated with concurrent training was considered when programming and 27 (63%) believed strength prior to aerobic training was more favourable for strength development than *vice versa*. This research represents the only published survey to date of S&C practices in Northern and Southern hemisphere RU.

KEY WORDS combined exercise, interference, physical preparation, programme design, questionnaire

INTRODUCTION

Rugby Union (RU) is a contact team sport that is popular worldwide. Match analysis has indicated that RU is a multi-directional, intermittent, invasion game incorporating multiple high intensity efforts. These vary in nature and consist of sprinting, accelerations and sport specific activities including tackling, rucking, mauling and scrummaging (12, 13, 30, 33). The physical demands of RU are specific to the individual positions (24). A 15-player side consists of forwards (n = 8) and backs (n = 7), the forwards are further subcategorised in to; “front row”, “second row” and “back row” positions. Backs also are subcategorised in to “half backs”, “centres” and “outside backs”. In many cases players are allocated to certain positions based on their anthropometric and physical performance characteristics, with forwards tending to be heavier and stronger and backs tending to be leaner and faster (11).

A growing body of research has examined the physical demands of competitive RU matches via performance, time motion and global position system analyses (8, 9, 33). More recent research has examined the influence of standardised and controlled conditioning interventions on physical performance phenotypes associated with successful RU performance (1, 3, 42). In addition, studies have investigated the influence of pre performance strategies including post activation potentiation (PAP) and hormonal priming on physical performance factors necessary for effective RU performance (2, 18, 26).

The availability of literature quantifying both the physical demands of elite RU and the influence of conditioning interventions has allowed practitioners to gain a greater understanding of the physiology of RU and potentially programme more effectively for their athletes. Despite this increased understanding, RU remains a challenging sport to support. In contrast to many (particularly Olympic) sports RU requires differing and in some cases contrasting physical qualities for successful performance. Research has indicated that strength and power (both absolute and relative to body mass) are important physical qualities in elite RU union (1, 11), in contrast as players can cover an average of ~7km during a competitive match(8) athletes also require aerobic and fatigue resistance capabilities (33). This required contrast may present practitioners with problems when programming as responses to strength and power training can be muted as a result of endurance type stimulus (21, 22, 25, 28). This inhibited strength development or “interference effect” (22) associated with concurrent strength and aerobic training also warrants consideration during training phases such as pre-season, in which practitioners often have limited time to promote gains in strength and power phenotypes.

Despite the growing global profile of RU and increasing attention in scientific literature there is little published information available pertaining to practices and strategies employed by strength and conditioning (S&C) and sports science practitioners in elite RU. Whilst S&C practices have been examined in various North American and Olympic sports (10, 14-16, 19, 38) there are no available data detailing how specific conditioning is prescribed and monitored in elite RU. In addition, is it is presently unknown if the “interference effect” associated with concurrent strength and aerobic type training is i) considered and ii) managed by practitioners working with RU athletes.

Information relating to common trends in training prescription and management could act as a useful reference source for applied practitioners. This information also may inform training programme design for future studies seeking to examine the influence of conditioning interventions in elite RU athletes. As such, the aim of this study was to survey and examine training and monitoring strategies of practitioners responsible for the S&C of RU athletes.

METHODS

Experimental Approach to the Problem

The survey titled "Strength and Conditioning Questionnaire" was adapted from that employed by Ebben and Blackard (14). The questionnaire was made specific to RU and pilot tested on a group of 7 S&C coaches. The survey contained 7 sections; personal details, physical testing, strength and power development, concurrent training, flexibility development, unique aspects of the programme and any further relevant information regarding prescribed training programmes. The survey was distributed to S&C coaches and sport scientists working with either professional rugby clubs/franchises/provinces or national teams in both the Northern and Southern hemispheres. It was hypothesised that this study would provide a comprehensive view of S&C and concurrent training practices in elite RU.

Subjects

Prior to all experimental procedures the Northumbria University research ethics committee approved the study. All subjects were informed of the risks and benefits of the investigation prior to signing an approved informed consent document to participate in the study. Surveys were sent out electronically via email and a survey collating website. Data were collected between September 2014 and February 2015.

Statistical analysis

The survey contained fixed-response and open-ended questions. Answers to open-ended questions were content analysed according to methods described by Patton (31), which have previously been used in other surveys of S&C practices in elite and professional sport (10, 15, 16, 38). Researchers had experience with qualitative methods of sports science and S&C research. When analysing data, investigators generated raw result data and higher order themes via inductive content analysis and compared individually generated themes until agreement was reached at all levels of analysis. When higher-order themes were developed, deductive analysis was used to confirm that all raw data themes were represented.

RESULTS

Personal Details

Forty-three (41 male, 2 female; 33.1 ± 5.3 y) of 52 (83%) coaches responded to the questionnaire. The respondents consisted of 21 S&C Coaches, 12 Head S&C Coaches, 3 Senior S&C Coaches, 3 Academy S&C Coaches, 2 Performance Managers and 2 Sport Scientists. Forty-two practitioners reported having fellow coaching and support staff. Examples of fellow coaching staff given by respondents were; “Assistants”, “Interns”, and other S&C staff such as Performance Mangers and “Travelling S&C Coach” (text in double quotes are direct quotations taken from questionnaires). Four practitioners were based in Australia, 3 in France, 4 in New Zealand, 2 in South Africa, 1 in Hong Kong, 1 in Japan, 1 in Samoa and 27 in the

United Kingdom. Information on the types of athlete coached by the respondents is presented in Table 1.

Table 1 about here

Formal Education

Seventy-nine per cent of respondents had an undergraduate degree in Sport and Exercise Science or a related subject and 61% held a master's degree in a Sport Science related field. In addition 2 coaches held Post Graduate Certificates in Education and 2 stated they were completing PhDs in Exercise Physiology and S&C.

Certification

The most commonly held professional certification was United Kingdom Strength and Conditioning Association Accreditation (n = 10). Nine respondents were Certified Strength and Conditioning Specialists with the National Strength and Conditioning Association (USA), 5 were accredited at various levels by the Australian Strength and Conditioning Association and 6 were British Amateur Weightlifting Association certified. Other qualifications held included; "British Association of Sport and Exercise Sciences High Performance Sport Accreditation", "International Society for the Advancement of Kinanthropometry Accreditation" and "United Kingdom Athletics Coaching Qualification".

Physical Testing

Forty-two of 43 respondents indicated that physical testing was conducted on their athletes. Participants were asked when testing was performed (Figure 1) and what aspects of physical performance were tested (Figure 2). The most commonly employed test of acceleration was 10m sprint time (n = 30). Tests of agility included; pro agility test, “reactive agility”, Illinois agility run, T-test, 5-0-5 test, change of direction and acceleration test (CODAT) and “in depth lateral jumps”. Measures of anaerobic capacity included Rugby Football Union (RFU) anaerobic test, Welsh Rugby Union (WRU) WAT test, “repeat sprint ability”, Yo-Yo test, “Watt-Bike repeat sprints (10 x 6s in at 30s intervals)”, “Watt-Bike 30s sprint”, “Watt-Bike 6 min test”, 500m rowing, phosphate decrement test, “3 x 60s running test”, “intermittent shuttle test”, anaerobic shuttle, “lactate test on treadmill”, “Bronco shuttle test”, “GPS work capacity”, “Australian 30s x 6 test”, Wingate test, “rugby anaerobic fitness test”, “150m Shuttle Test”, “club specific conditioning test”, “rugby specific testing”, “anaerobic training threshold zone (ATTZ) runs” and “6 x 30m sprints”.

Figure 1 about here

The most commonly employed measure of body composition was sum of 8 site skinfolds (n = 22) with 7 (n = 5) and 3 (n = 1) site skinfolds also utilised. Other measures of body composition included; body mass, height, dual-energy X-ray absorptiometry (DEXA), body fat% and one respondent designed their own method of assessing body composition, although no other details were given. Twenty-three respondents stated that the Yo-Yo incremental test was utilised as a measure of cardiovascular (CV) endurance, other employed tests of CV endurance included; 1500m run, “30-15 aerobic test”, “a 4min shuttle test”, 1km run, “MAS test TUB 2”, “1km repeat”, “3min Watt-Bike test”, 2.4km time trial, “7min test”, “modified bleep test", "Watt-Bike 20min test", "GPS work capacity", "incremental treadmill test", "ATTZ test" and "1.6km time trial".

Functional movement screening (FMS) was the most commonly utilised measure of flexibility (n = 8), other measures of flexibility included; "physio screening" "subjective assessments", sit and reach test, "physical competency assessment", Thomas test, hamstring capacity, thoracic rotation, knee to wall test, "internally developed movement competency screen", "range of motion tests" and overhead squat. Seventeen respondents tested indices of muscular endurance (Figure 2), these included; glute bridge, calf raise, max push ups, max sit ups, "modified test involving body weight exercises and timed run devised around facility layout", max chins, max dips, max pull ups, "capacity tests on calves, glutes and hamstrings", plank, side plank, back extension and single leg glute bridge.

Figure 2 about here

The most commonly employed test of muscular power was maximum countermovement jump (CMJ) height (n = 19), 11 (26%) practitioners assessed 1 – 3 repetition maximum (RM) in Olympic lifts (clean or snatch) or their variations (i.e. from hang position), additionally 17 (40%) assessed reactive strength index (RSI) or other jump variations including; broad jumps, drop jumps, squat jumps, "triple response jumps" *etc*. A variety of other measures of muscular power were utilised by respondents including; "velocity test", velocities of movements via "GymAware" and "Attacker" systems, 10 and 30m sprints, tendon stiffness, 1RM in bench press, back squat and half squat, "bench throw and pull", peak power output in 6s on Watt-Bike and medicine ball throw. Twenty-eight practitioners utilised 1RM testing to assess muscular strength with bench press (n = 22) and back squat (n = 20) the most common lifts. Other methods of assessing muscular strength included mid-thigh isometric pulls on a force plate and “predicted RMs taken from strength training performance”. All 37 respondents who stated they testing speed phenotypes examined sprint times with distances ranging from 10 – 80m, additional speed tests employed included; “speed bounce” and GPS maximum velocity.

Strength and Power Development

The initial question in the section asked if practitioners believed that strength training benefits RU performance, all 43 respondents answered yes. Eight practitioners left additional comments such as; “stronger players are more resilient”, “it helps the players develop the appropriate physical qualities that are required to play the game”, “But a focus on quality of lifting through a full range if safe for the athlete is critical as well as the combination of movement skills, awareness and integration with the rest of the rugby programme is critical to maximum carryover into performance” and “it is a very important part of preparation but in my experience it's importance is overstated by the rugby community”. All 43 respondents also stated that strength training was regularly performed by their athletes.

In-Season Training

The current section was divided into 2 subsections, the first of which focused on in-season strength and power training practices. The first question in this subsection asked how many days of the week that in-season strength and power training was performed; one practitioner reported $1d\cdot wk^{-1}$, 14 reported $2d\cdot wk^{-1}$, 35 reported $3d\cdot wk^{-1}$, 4 reported $4d\cdot wk^{-1}$ and 1 reported $5d\cdot wk^{-1}$.

The second question within this subsection asked coaches to detail the days of the week in which strength and power training is performed in relation to next scheduled match day (MD); six practitioners reported MD-6, thirty one reported MD-5, thirty six reported MD-4, fourteen reported MD-3, thirty five reported MD-2, six reported MD-1 and three reported strength and power training was conducted on MD. The third question in this section asked practitioners the typical duration of an in-season strength and power session; two practitioners reported 15-30min, twelve reported 30-45min, twenty six reported 45-60min and seven reported 60-75min. The final question in the subsection asked practitioners to indicate the number of sets and repetitions typically used for strength training exercises in-season. Responses were content analysed and resulted in the creation of 5 higher order themes, including; i) set range of 3-5, ii) set range including >5 sets, iii) rep range of 3-5, iv) rep range including >5 reps and v) miscellaneous. Further information on higher order themes, practitioner responses and representative raw data is presented in Table 2.

Table 2 about here

Off-Season Training

The first question in the off-season subsection asked practitioners the number of $d\cdot wk^{-1}$ their players engage in strength training. Three practitioners reported $2d\cdot wk^{-1}$, eleven reported $3d\cdot wk^{-1}$, twenty-five reported $4d\cdot wk^{-1}$, ten reported $5d\cdot wk^{-1}$ and four reported $6d\cdot wk^{-1}$. The following question addressed the average length of an off-season strength/power session; two respondents reported 15-30min, four reported 30-45min, twenty two reported 45-60min, twelve reported 60-75min and one reported >75min.

The final question in the off-season training subsection asked practitioners to indicate the number of sets and repetitions typically used for strength training exercises during the off-season. Content analysis resulted in the creation of 5 higher order themes including; i) set range of 3-6, ii) set range including >6 sets, iii) rep range of 3-8, iv) rep range including >8 reps and v) miscellaneous. Further information on higher order themes, practitioner responses and representative raw data is presented in Table 3.

Table 3 about here

Programme Design

The initial question in this subsection asked whether practitioners included Olympic style weightlifting exercises in their prescribed training programme. Thirty-eight respondents indicated that Olympic style weightlifting exercises were included in conditioning programmes.

The next questions within this subsection were related to recovery time prescribed between i) an Olympic weightlifting style strength session and a high-quality rugby training session, ii) a general strength training session and a high quality rugby training session, iii) an Olympic weightlifting style strength session and a competitive rugby match and iv) a general strength training session and a competitive rugby match. Responses to these 4 questions are detailed in Table 4. Practitioners were then asked the extent to which they agreed that strength and power training influenced rugby performance; twenty-six coaches indicated they strongly agreed, 14 strongly agreed and 1 indicated they were unsure. The next question asked coaches to identify and rank the top 5 weightlifting exercises that are most important in their programmes, responses to this question are detailed in Table 5.

Table 4 about here

Table 5 about here

Question 7 in this subsection asked practitioners if they used periodisation strategies to structure training plans. Thirty-eight (88%) respondents indicated that periodisation strategies were used. Practitioners comments in response to this question included; “To target specific outcomes in a specific period”, “Better long term results, prevents stagnation”, “Monitoring and assessing load and volume with intensity is vital, so you need to know when to delay and load at appropriate times of the year”.

The final question in this section asked practitioners how load (weight) was determined during typical strength training sessions. Responses were content analysed into 4 categories including; (a) RM and max strength testing, (b) athlete led, (c) coaches subjective assessment and (d) periodisation and phase of training. Data pertaining to higher order themes, total number of practitioners whose responses made up the theme and selected raw data within higher-order themes are presented in Table 6.

Table 6 about here

Speed Development

Forty of 43 (93%) respondents who completed the survey reported incorporating aspects of speed development in their programming. Responses were content analysed and resulted in the creation of 6 higher order themes; (a) un resisted (free) sprinting, (b) plyometrics, (c) sprint mechanics and technique, (d) resisted sprinting, (e) improving max strength and (f) Olympic lifting. Table 7 details the aforementioned higher order themes, the total number of coaches whose responses made up the theme, and select raw data within each higher order theme.

Table 7 about here

Plyometrics

Forty-one (95%) respondents reported using plyometrics. The subsequent question in this section asked why coaches prescribed plyometrics, 16 (37%) coaches reported prescribing plyometrics for improving rate of force development, 7 (16%) for training the stretch shortening cycle, 4 (9%) for improving stiffness and 2 (5%) for injury prevention. The third question in this subsection focused on the phases of the year plyometrics are used, Figure 3 illustrates the responses to this question.

Figure 3 about here

The forth question in this subsection examined integrated plyometrics. Responses were content analysed and resulted in the creation of 4 higher-order themes; (a) within strength and/or power session, (b) dependant on Individual athlete, (c) within warm up and (d) part of movement skills. Table 8 lists the higher-order themes, number of practitioners whose responses make up the theme and representative raw data within each theme. The final question within this subsection asked practitioners to identify types of plyometric exercises regularly used in their programme. Reponses to this question are detailed in Figure 4.

Figure 4 about here

Flexibility development

Forty-one (95%) practitioners indicated that some form of flexibility training was included in players' physical programmes. Thirty (70%) respondents indicated that static stretching was performed, 26 (60%) reported using proprioceptive neuromuscular facilitation (PNF) and 37 (86%) indicated dynamic stretching was performed. Six (14%) respondents reported using other methods of flexibility development including; yoga, body balance, band distraction, and stretch bands. The following question asked practitioners when their athletes performed flexibility training, the typical duration of flexibility sessions and the duration athletes were encouraged to hold a static stretch. Results from these questions are presented in Figures 5 – 7.

Figure 5 about here

Figure 6 about here

Figure 7 about here

Concurrent strength and endurance training

The first question in the subsection asked practitioners if they considered any potential muting effect of endurance training on strength/hypertrophic development, 33 (77%) practitioners indicated they did and 8 (19%) indicated they did not. Reasons for not considering any potential interference effect consisted of; “Rugby is concurrent”, “Players must develop both motor qualities” and “If programmed correctly can balance both into programmes”.

The following question in this subsection asked practitioners how important they felt it was to consider any concurrent training effect when programming for strength/hypertrophic development (1 = not important at all and 5 = most important), the responses to this question are detailed in Figure 8. The penultimate question asked participants to rank the following programme variables in order of importance when attempting to avoid any muting effect of endurance type stimulus on strength/hypertrophic development; periodisation, order of strength and endurance training, volume of endurance training, volume of strength training and time between strength and endurance training. Responses to this question are detailed in Table 9. The final question in this section asked practitioners which order of strength and endurance training they felt was more conducive to strength and/or hypertrophic development, 27 (63%) practitioners believed strength then endurance training was more favourable and 12 (28%) believed endurance then strength.

Table 9 about here

Figure 8 about here

Unique aspects of the programme

The unique aspects (if any) of practitioners physical conditioning were content analysed and divided into 5 higher order themes; (a) individualisation, (b) nothing unique, (c) miscellaneous, (d) integration and (e) periodisation. Table 10 details these themes and the number of practitioners' responses that make up each theme. The second question within this section asked practitioners what they would like to do differently in their conditioning programmes. Responses were content analysed and resulted in the creation of 6 higher-order themes; (a) have more time, (b) miscellaneous, (c) improved facilities/equipment, (d) greater individualisation, (e) improved monitoring and (f) more staff. Table 11 details these themes and the number of practitioners' responses that make up each theme.

Table 10 about here

Table 11 about here

DISCUSSION

The present study sought to conduct a comprehensive survey of S&C and concurrent training practice in elite RU. To the authors' knowledge this is the first qualitative assessment of practitioners S&C practices in RU. A total of 43 practitioners responded to the questionnaire, this is the highest number of responses obtained in a study examining S&C provision in a single sport. Previous studies examining S&C practices in North American sports have received between 20 and 26 responses (14-16, 38) and a more recent study in British Rowing received 32 responses (19). The response rate to our survey was high (83%), previous comparable studies have reported return rates of between 69-87%. As such, 43 responses at a return rate of 83% were deemed sufficient for analysis. Many respondents stated they worked with more than 1 level of RU athlete. The most commonly supported level of athlete played for either a professional club, province or franchise and/or a national team (30 and 24 responses). Therefore, the data presented in this article are reflective of elite RU.

Practitioners reported testing 11 aspects of physical fitness (additional are details presented in Figure 2). This number is notably more than previously reported in other sports including Major League Baseball (MLB) (3-4 aspects) (16), National Hockey League (NHL) and National Basketball Association (NBA) (7-8 aspects) (15, 38) and Rowing (4-5 aspects) (19). The 11 aspects of physical fitness tested in the present study are, however, similar to that previously reported in National Football League (NFL) (9-10 aspects) (14). It is possible that this is reflective of the similarities between RU and NFL as they are both contact, intermittent, invasion based team sports. However, comparisons should perhaps be interpreted with caution as Ebben and Blackard (14) reported S&C practices in NFL in 2001 and it is very likely that assessment batteries in NFL have progressed and been adapted over the past ~14 years.

The most commonly tested aspect of physical fitness was body composition, which was assessed by 40 of 42 (95%) of practitioners. Similarly, body composition was commonly assessed by practitioners working with North American sports with 83-100% of respondents indicating body composition was assessed (14-16, 38). To the authors' knowledge there are no empirical data demonstrating that "favourable" changes in body composition (increased lean mass and lower levels of subcutaneous fat) result in improved RU performance. However, when % body fat from separate studies are combined, a linear relationship between playing standard and % body fat is evident and it appears that as playing standard increases % body fat of RU athletes decreases (full summary provided by Duthie et alv(11)). It is also reasonable to suggest that increases in lean mass and reduction in % body fat may result in improvements power to body mass ratio, acceleration and other performance phenotypes associated with RU performance. Monitoring body composition may also be useful for assessing (any) gains in lean mass following any prescribed hypertrophy type training. Other commonly assessed aspects of physical fitness were max speed, muscular power (both 37), acceleration and muscular strength (both 36). It is likely this indicates the practitioners who responded to the survey consider these physical qualities important for RU performance. There was a notable variance in measures of anaerobic capacity employed, with 17 different measures employed across the 31 practitioners who indicated that they performed anaerobic capacity testing. This may indicate there is a need for future work to construct a valid and standardized protocol for assessing anaerobic capacity in RU athletes. Overall physical testing was most commonly conducted pre and in season with 41 and 38 respondents indicating physical testing was conducted during these phases.

All 43 respondents indicated strength training was regularly performed by their athletes; in addition all practitioners believed strength training is beneficial for RU performance. This belief is supported by research indicating RU performance requires high levels of contractile strength (29, 35). Thirty-eight of the 43 practitioners (90%) reported implementing Olympic style weightlifting exercises within strength and power training. This practice is similar to those reported in Rowing (87% of practitioners surveyed), NFL (88%), NBA (95%) and NHL (91%) (14, 15, 19, 38). These data indicate Olympic style weightlifting exercise are widely prescribed in team sports and rowing, this prescription is most likely due to the association with Olympic lifting training and improvement in power output and acceleration (5, 41) which have been identified as important physical qualities in RU and other sports (33, 37). The squat and clean were considered the most important exercise within players training programmes. The aforementioned lifts were seen also as the 2 most important by practitioners working in Rowing, NBA, NFL and NHL (14, 15, 19, 38). Gee et al (19) hypothesised that the clean and squat are valued across a range of sports as they relate to sports specific performance phenotypes such as sprint and jump ability (23, 32).

With regard to strength training frequency, 35 (81%) practitioners reported prescribing strength training 3 $d \cdot wk^{-1}$ in-season, while in the off-season 25 (58%) practitioners reported prescribing strength training 4 $d \cdot wk^{-1}$. The most common set/rep/load scheme prescribed in season was 3-5 sets of >5 reps based on RM and max strength testing, this scheme differed to the most common prescription of 3-6 sets of >8 based on RM and max strength testing. This increased volume of strength training also was reflected in practitioners' comments which included "during the off season we typically use higher volumes". These alterations in strength training volume may reflect the shift of conditioners focus from maintenance (in-season) to development (off-season) of physical qualities and that S&C staff tend to have more contact time with athletes outside the competitive season (anecdotal observations and reports from practitioners).

Speed development training was prescribed by 40 respondents (93%), which is similar to that reported in NFL, MLB, NBA (all 100%) and NHL (96%) (14-16, 38). Un resisted or "free" sprinting was the most popular method of speed development, training methods included "max speed running" and "track sprinting". The second most popular method of speed development was plyometrics and 41 (95%) respondents reported implementing plyometrics within their conditioning plans (for speed development or otherwise). As with speed development, this method is similar to NBA (100%), MLB (95%) and NHL (91%) (15, 16, 38). It is somewhat surprising that the prevalence of plyometrics prescribed in NFL was notably lower (73%) (14) that that in RU given that both sports require physical qualities such as power and acceleration for successful performance (4). However, as previously stated it is likely that S&C practices in NFL have changed since the study of Ebben and Blackard (14) was conducted.

Thirty-eight of 43 respondents (90%) reported implementing periodisation strategies in their conditioning programmes, this practice is similar to that of coaches in Rowing (97%), NBA (91%), NHL (90%) and MLB (83%) (15, 16, 19, 38). Periodisation strategies have been demonstrated to result in greater improvements in strength, power and body composition than linear training (27, 40). Periodisation has also been reported to be an effective means of avoiding any potential muting effect of aerobic type stimulus on strength and power development (17). Thirty-three respondents (77%) indicated that the "interference effect" associated with concurrent strength and aerobic training was considered whilst programming for RU athletes. In addition, 20 (47%) practitioners believed it was very important to consider when constructing conditioning plans. As previously stated periodisation has been reported to be an effective means of concurrently developing strength and aerobic physical qualities (17), as such it is perhaps unsurprising that periodisation was ranked as the most important programme variable when attempting to avoid any interference effects (Table 9). Time between strength and endurance training was considered the least important variable to consider. This finding is somewhat surprising as research has indicated allowing sufficient time (≥6h) between strength and aerobic stimuli allows strength development to occur uninhibited (17, 34). In addition elite Kayakers have been reported to separate strength and aerobic training sessions by 6 – 8h to allow full glycogen restoration (17). The majority of practitioners scheduled strength and Olympic lifting sessions (72% and 79% respectively) on the same day as high quality RU sessions, however the recovery period afforded between sessions was not detailed.

Twenty-seven (63%) practitioners believed strength prior to endurance training was more conducive to strength development rather than *vice versa*. Researchers have reported similar magnitudes of strength development when strength training is conducted prior endurance training and *vice versa* (6, 20, 36). However, Collins and Snow (7) reported maximal strength development was greater when strength training was conducted subsequent to endurance training rather than *vice versa*. In contrast, it has been reported that in well trained individuals strength training performance is lessened for up to 8 h post aerobic type training (39), which over time may result in muted strength development. As such it presently remains unclear which order of concurrent strength and aerobic training is most favourable for strength development and how it should be programmed in sports such as RU which require both strength and aerobic physical qualities.

From analysis of survey data, key research findings emerged. Physical testing was commonly conducted amongst practitioners with body composition, max speed, muscular power and strength and acceleration being the most commonly tested variables. Olympic lifting was widely prescribed within strength training and most practitioners employed periodisation strategies when programming. Most respondents consider the interference effect associated with concurrent strength and aerobic training and many believed it was an important factor to consider whilst programming. Periodisation was identified as the most common programme variable to consider when attempting to avoid any muting effect of endurance stimulus on strength/hypertrophic development, whereas time between strength and aerobic stimuli was considered the least important. With further regard to concurrent training most practitioners believed strength prior to endurance training was more favourable for strength development than *vice versa*. Un resisted/free sprinting was the most popular method of speed development and plyometrics were the second most popular. Plyometrics were also prescribed by almost all practitioners for the development of physical qualities such as speed, power and acceleration.

PRACTICAL APPLICATIONS

This study describes S&C and concurrent training practices of practitioners supporting RU athletes in the Northern and Southern hemispheres. As most respondents supported international and/or professional level RU athletes, practitioners now have a source of data describing S&C practices at the elite end of RU. Coaches and sports science practitioners who work with RU athletes at all levels of the game may use this summary of S&C practices as a resource to inform and improve their practices. Information presented in this article may also influence the design of experimental protocols in future studies investigating effects of conditioning interventions on physical performance phenotypes associated with RU performance.

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Figure Legends

Figure 1. Times when physical performance phenotypes are assessed.

Figure 2. Physical phenotypes tested.

Figure 3. Times in which plyometrics are conducted.

Figure 4. Specific plyometric exercises prescribed.

Figure 5. Times when athletes were encouraged or required to perform flexibility exercises.

Figure 6. Duration of a typical flexibility session prescribed by coaches.

Figure 7. Amount of time athletes are encouraged to hold a static stretch.

Figure 8. Importance of considering of concurrent training effect when programming for strength/hypertrophic development (1 = not important at all, 5 = most important).