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Effect of a 6-week exercise intervention for improved neck muscle strength in amateur male rugby union players.

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ABSTRACT

Neck strengthening for players in impact sports like rugby is receiving greater attention lately due to postulated associations with head and neck injury and concussion and while research is available on the effectiveness of neck strengthening interventions on professional rugby players, the same research has not been conducted on amateurs who make up the majority of rugby players. The aim of this study was to investigate the effectiveness of a 6-week neck strengthening intervention on a group of male amateur rugby union players (20.1 ± 2.0 yr, mean ± SD). In a randomized controlled trial, players worked with their trainer to practice neck-specific strengthening exercises 3 times per week for 6 weeks (strength group, n = 22) or performed no additional neck strengthening exercises (control group, n =17). Isometric maximal voluntary contraction (MVC) was measured pre and post the intervention in 4 different directions (flexion, extension, left and right lateral flexion). Compared to the control group the strength group improved neck strength in all directions except flexion (flexion 7.1 ± 13.0 kg, mean ± SD, 75/18/7%, chances of positive/trivial/negative increase in strength, p = 0.28; extension 13.5 ± 14.6 kg, 92/7/1%, p = 0.07; left lateral flexion 13.5 ± 11.3 kg, 97/3/0%, p = 0.02; right lateral flexion 13.8 ± 14.9 kg, 92/7/1%, p = 0.07. Our results indicate that a simple 6-week neck strengthening program improves isometric MVC strength in male amateur rugby players.

1. Introduction

Rugby union is a fast moving collision sport that involves relatively short periods of high-intensity sprinting, interspersed with long periods of lower-intensity exercise (walking/jogging) (Jones, West, Crewther, Cook, & Kilduff, 2015). Rugby union also involves a high number of collisions (King, Cummins, Hume, Clark, & Pearce, 2018) which can occur from tackling, scrummaging, rucking, mauling and colliding with the ground or other players. Due to the physical nature of the game, a rugby player's body must be able to sustain considerable stress which results in significant tissue damage (Lindsay et al., 2016) and may result in injury (Quarrie et al., 2001).

The explosive and dynamic characteristics of the game means a rugby player's body is occasionally placed in compromising positions, particularly during the initial physical contact of a tackle, and it's the tackle that is associated with the highest risk of injury (Fuller et al., 2010; McIntosh, McCrory, Finch, & Wolfe, 2010; Quarrie & Hopkins, 2008). Often the neck and shoulders are intricately involved in the tackle situation, and, some researchers have postulated an association between neck strength and reduced injury incidence (Frounfelter, 2008). Moreover, since cervical musculature is the tissue mainly responsible for neck and head stabilization (Panjabi et al., 1998), any fatigue or weakening of neck strength during a rugby game may compromise its supportive role and place the player at an increased risk of neck injury (Collins et al., 2014).

Previous research on civilians (Nikander et al., 2006) and pilots (Äng, Monnier, & Harms-Ringdahl, 2009) has reported a significant reduction in neck pain after a structured exercise program targeting the cervical muscles. This correlation between neck strengthening exercises and reduced neck pain lead to the

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suggestion that specific neck strengthening may help to reduce neck injuries (Salmon et al., 2011), and possibly concussion (Collins et al., 2014). In a cross-sectional study of over 6000 high school students, Collins et al. (2014) reported that overall neck strength was a significant predictor of concussion. More recently, female soccer players with weaker neck strength sustained significantly greater head impacts while heading the soccer ball (Gutierrez, Conte, & Lightbourne, 2014). Similarly, Eckner et al. (2014) showed that athletes with greater neck strength reduced the magnitude of the kinematic response to impulsive loads (Eckner, Oh, Joshi, Richardson, & Ashton-Miller, 2014). However, other researchers using a head and neck model in lab experiments have reported that increased cervical muscle force does not influence short term head kinematics (Eckersley, Nightingale, Luck, & Bass, 2019).

Even though the hypothesized reduced concussive risk with increased neck strength requires more experimental evidence (Toninato et al., 2018), improved neck strength has been associated with reduced neck pain (Nikander, Mälkiä et al. 2006, Äng, Monnier et al. 2009) and injury (Naish, Burnett et al. 2013, Collins, Fletcher et al. 2014). Therefore, neck strength training, particularly in collision sports such as rugby union, may have a positive impact on injury incidence, but very little information exists on the potential to improve neck strength in rugby players. One previous article has indicated the effectiveness of neck strength training in professional rugby union players (Geary, Green, & Delahunt, 2014), however the vast majority of players are non-professional (amateur club rugby) athletes who are generally lighter, weaker (Smart, Hopkins et al. 2013), and have less opportunity to utilize professional strength and conditioning expertise during training compared to professional athletes.

In general, forwards are involved in more physical impacts during a game (Takamori, Hamlin et al. 2020), particularly in the ruck and maul but also during scrums where more stress is exerted on the neck and shoulders. Neck strength is therefore an important fitness component for forwards and most forwards are accustomed to training their neck muscles. Backs on the other hand, are involved in a fewer number of impacts (Takamori, Hamlin et al. 2020), and in our experience, devote less time to training areas such as the neck muscles. Therefore, part of this study was to split the rugby players into forwards and backs to investigate whether the strength training protocol was effective for relatively experienced (forwards) and inexperienced (backs) neck-training groups.

Therefore, this study aimed to investigate the effectiveness of a specific 6-week neck strengthening program on the neck strength of non-elite amateur senior premier level rugby players (both forwards and backs) that may then be utilized by club coaches and strength and conditioning personnel to assist with training and development of these non-elite athletes.

2. Methods

A randomized controlled trial was conducted where neck strength was tested twice (pre and post) to determine the effectiveness of a targeted 6-week neck strengthening program on amateur senior premier rugby players. Isometric neck strength was measured in a seated upright position in the flexion, extension, left lateral flexion and right lateral flexion positions.

2.1. Participants

Thirty-nine players from the Christchurch region in New Zealand participated in this study which was conducted over 6 weeks (Table 1). Players were uninjured young non-professional male rugby union players currently training in a provincial development academy or a university sports scholarship program. Subjects continued with their regular competition-season training during the 6 weeks of the study which included 3 gym sessions, 2 skill sessions, 2 conditioning sessions and 1 competition game per week. All protocols for this study were submitted to and approved by the local University Human Ethics Committee (reference 2019-22). All players were over the age of 18, and informed of the benefits and risks of the investigation prior to signing an institutionally approved informed consent document to voluntarily participate in the study.

Table 1: Physical characteristics of the rugby players in each training group.

	Control (n = 17)	Strength (n = 22)
Age (yr)	20.5 ± 2.0	19.9 ± 2.0
Height (cm)	181.0 ± 7.6	183.5 ± 5.3
Weight (kg)	91.0 ± 17.6	97.6 ± 12.4
Lean body mass (kg)	73.4 ± 9.2	75.3 ± 14.4
Body fat (%)	18.1 ± 8.6	19.3 ± 5.4
Neck girth (cm)	40.7 ± 3.2	42.4 ± 2.3
Neck length (cm)	7.8 ± 1.9	7.6 ± 1.2
Forwards/backs (n)	9/8	13/8
Playing history (yr)	12.8 ± 3.4	12.4 ± 3.9

Data are mean ± SD except for the number of forwards and backs in each group.

2.2. Strength Testing

Participants were given a familiarization session on testing equipment and protocols approximately 1 week prior to the baseline testing. Players were instructed not to change their diet throughout the study. Players were instructed to present themselves for testing in a rested and hydrated state, having avoided heavy exercise and the consumption of alcohol in the preceding 24 hours, and having avoided consuming a heavy meal and caffeinated beverages in the preceding 2 hours.

Testing for each subject was completed at approximately the same time of day (± 1 hour) at the research lab located close to where the athletes train. Prior to the baseline test, the player's height was measured to the nearest 0.1 cm with shoes and socks removed using a portable stadiometer (Seca 213, Hamburg, Germany). Bioelectrical impedance analysis (Accuniq, BC380, Korea) was performed to assess participants lean body mass, body fat percentages and total body mass. Participants were asked to void their bladders prior to measurement to minimize measurement error. Neck girth was taken superior to the thyroid cartilage with the head in the Frankfort plane. The measurement was taken while the participants were seated by having the Lufkin steel tape held perpendicular to the long axis of the neck and recording to the nearest 0.2 mm (Norton et al., 1996). Neck length was measured using a sliding steel bone caliper from the spinous process of the vertebral prominence (C7) to the occipital notch at the base of the skull, while the head was in the Frankfort plane (Olivier & Du Toit, 2008). The same examiner recorded the average of 2 girth and length measurements.

To ensure consistency, players were required to complete a standardized warm-up procedure which consisted of 3 sets of 10 reps of shoulder elevations and depressions, shoulder circumduction, shoulder protractions and retractions, and neck half circles in each direction. After the warm-up isometric neck strength was measured using a commercially available head harness (Neck Flex, USA) attached to a load cell (10Hz, Tesion/S-beam load cell, AST 500, PT Instruments, UK) fixed to an immovable squat rack set-up (Figure 1). During the test, participants sat on an incline bench press chair with their back upright and arms folded across their chest. Participants were held in place by 2 Velcro straps around the upper and lower torso to avoid movement of the torso and lower body, thereby isolating the neck muscles during testing. The head harness was fitted to each participant so that the lower border of the harness was aligned with the eyebrow line (Figure 1) and that the starting position was at a neutral position where the head was aligned with the torso and spine (Strimpakos, Sakellari, Gioftsos, & Oldham, 2004). For each test, participants were asked to perform an isometric maximal voluntary contraction (MVC) in flexion, extension, left lateral flexion and right lateral flexion positions. To avoid ballistic movements, participants were asked to first take the strain, and then over a 2-3 second period gradually increase the force to maximal exertion to be held for 3 seconds. Verbal encouragement was provided for each MVC (3 trials in each of the 4 head positions) and a 60-second rest period was given between each trial (Salmon, Handcock, Sullivan, Rehrer, & Niven, 2015). The peak force (kg) was recorded during the 3-second MVC.

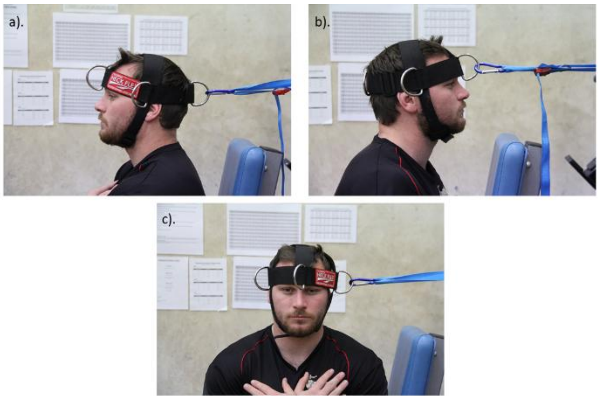

Figure 1: Experimental set up for testing players isometric MVC in a) flexion, b) extension, and c) right lateral flexion.

2.3. Strength Training

The 22 players in the strength group undertook a 6-week neck strengthening program performed three times per week under the guidance and advice of a strength and conditioning coach. Players completed four exercises each day including; weighted head harness isotonic extension, weighted isometric flexion and weighted head harness isotonic lateral flexion left and right (Figure 2). In the weighted head harness exercises, the head harness was adjusted for the height of the player then players completed 3 sets of 10 reps (week 1-2), 8 reps (weeks 3-4) and 6 reps (weeks 5-6). For the isometric flexion exercises players completed 2 reps of 40s (week 1), 2 reps of 30s (week 2), 2 reps of 20s (week 3), 3 reps of 15s (week 4), 3 reps of 10s (week 5) and 4 reps of 5s (week 6). Due to the unique nature of this training we calculated training load via the resistance training specific rating of perceived exertion (Zourdos et al., 2016), where players adjusted the load lifted according to a 10-point Likert scale where 1-2 is little or no effort and 10 is maximal effort (Helms, Cronin, Storey, & Zourdos, 2016). The load was therefore adjusted to give a perceived rating of 8 in set 1, 9 in set 2 and 9-10 in the last set.

Figure 2: Exercises used in the neck strengthening intervention program. a, b) weighted head harness isotonic extension, c) weighted isometric flexion, d, e) weighted head harness isotonic lateral flexion (right and left).

2.4. Statistical Analysis

Changes in the peak measurement from the 3 trials (highest force generated from all 3 trials) and standard deviations representing the between-and within-subject variability were estimated using a mixed modelling procedure (Proc Mixed) in the Statistical Analysis System (Version 9.3, SAS Institute, Cary, North Carolina, USA). The differences in peak isometric MVC were compared between groups and Cohen's value of 0.2 of the between-subject standard deviation was used to assess the smallest worthwhile change (Cohen, 1988). Results are displayed as mean ± SD or raw change ± 95% confidence interval. All data were assessed using the clinical inference, which is more conservative regarding the risk of harm (Batterham & Hopkins, 2006). In this regard, an odds ratio of benefit:harm was only accepted if it was above 66%; if not, the effect was considered "unclear". The magnitude of the change was reported using the following scale <0.5% = most unlikely; 0.5–5% = very unlikely; 5–25% = Unlikely; 25–75% = possibly; 75–95% = likely, 95–99.5% = very likely, >99.5% = most likely (Hopkins, Marshall, Batterham, & Hanin, 2009). P-values are also given for the between-group comparisons for those who use traditional hypothesis testing. We used an alpha level of $p \leq 0.05$ for significance in this study and calculated the effect size statistics (ES) from the change in the mean between groups divided by the between subject SD. The best measure of reliability is the standard error of the estimate (also known as the typical error of the estimate) (Smith & Hopkins, 2012) which is reported along with the intraclass correlation coefficients (ICCs) for the MVC values from the 3 trails for each of the 4 directions. A Pearson correlation was also conducted to investigate the association between key dependent variables.

3. Results

There were no substantial differences between the control and strength groups at baseline for any of the measured characteristics (Table 1). Separating the players into broad playing categories, we found at baseline that forwards had a substantially higher total body mass, lean body mass, percent body fat and neck girth compared to backs (Table 2).

Table 2: Physical Characteristics of the forwards compared to the backs.

	Forwards (n = 23)	Backs (n = 16)	Between Group Difference (± 95% CL)	Between Group Effect Size
Age (yr)	20.4 ± 1.9	19.8 ± 2.0	-0.6 (1.3)	0.3
Height (cm)	183.6 ± 5.9	180.7 ± 7.0	-2.9 (4.1)	0.4
Weight (kg)	102.4 ± 13.0	83.8 ± 10.6	-18.5 (8.9)*^	1.2
Lean body mass (kg)	78.7 ± 6.3	68.4 ± 16.1	-10.3 (7.5)*^	0.8
Body fat (%)	22.2 ± 6.6	13.8 ± 3.6	-8.4 (4.1)*^	1.2
Neck girth (cm)	42.8 ± 2.4	40.1 ± 2.6	-2.7 (1.6)*^	1.0
Neck length (cm)	7.8 ± 1.8	7.5 ± 0.9	-0.3 (0.9)	0.2
Flex (kg)	59.7 ± 15.3	56.3 ± 11.9	-3.3 (9.5)	0.2
Ext (kg)	67.8 ± 15.4	62.9 ± 15.9	-4.9 (10.8)	0.3
LeftFlex (kg)	58.7 ± 12.4	55.8 ± 16.5	-2.9 (8.7)	0.2
RightFlex (kg)	58.7 ± 15.5	62.9 ± 19.3	4.2 (11.0)	0.2

Data are mean ± SD of each group with the difference between groups given as the mean ± 95% confidence interval and the effect size of this difference. Flex, flexion; Ext, extension; LeftFlex, left lateral flexion; RightFlex, right lateral flexion
*Statistical significance ($p < 0.05$); ^Clinically substantial change between groups.

Neck strength over the course of the 6-week period changed little in the control group, however neck strength in all directions except flexion showed clear increases in the strength training group after the 6-week training period (Table 3). Compared to the control group, neck strength was likely or very likely to be increased in the strength group post training except in flexion (flexion 7.1 ± 13.0, mean ± SD, 75/18/7%, chances of positive/trivial/negative increase in strength, $p = 0.28$; extension 13.5 ± 14.6, 92/7/1%, $p = 0.07$; left lateral flexion 13.5 ± 11.3, 97/3/0%, $p = 0.02$; right lateral flexion 13.8 ± 14.9, 92/7/1%, $p = 0.07$). Players undertaking neck strength training improved regardless of whether they were forwards or backs with no statistically significant or clinically relevant differences between groups (Table 4). The coefficient of variation indicating the reliability of the MVC measurements over the 3 trials at baseline was 8.4% (flexion), 11.1% (extension), 10.5% (left lateral flexion) and 10.4% (right lateral flexion). Similarly the ICC ranged from 0.92 (right lateral flexion) to 0.86 (flexion), suggesting reasonable reliability in the measurement.

4. Discussion

This randomized controlled experiment aimed to determine whether the implementation of a 6-week neck strengthening program was effective at improving the isometric strength of amateur rugby union players. The main finding was a clinically worthwhile increase in isometric strength in three of the four movement directions (extension, left and right lateral flexion). While other researchers have investigated the effectiveness of neck strengthening programs on elite rugby players (Geary et al., 2014; Naish, Burnett, Burrows, Andrews, & Appleby, 2013), helicopter pilots (Äng et al., 2009; Salmon et al., 2013), and office workers (Nikander et al., 2006), as far as we know, this is the first to report the effects of such training on non-elite amateur senior premier level rugby players. This is an important finding as the vast majority of rugby players are amateurs and therefore these athletes should expect to gain similar results if they follow the training program outlined in this study.

Overall, compared to the control group the players that completed the 6-week neck strengthening program in this study improved their isometric neck strength by approximately 12-24% which equates to a moderate to large effect size (Table 3). Such strength changes are similar to increases reported by Geary et al. (2013) on professional rugby union players after 5-weeks of isometric training (17-21%), but are in contrast to the findings of Naish et al. (2013) who found small (1-4%) and not statistically significant changes in neck strength on similar players after 13 weeks of isometric neck strength training. It may be argued that professional rugby players are well-conditioned athletes and that a ceiling effect may be responsible for the differences in results (Naish et al., 2013). However, this seems unlikely since the average isometric MVC from all 4 neck directions was lower in Naish et al. (2013) (~ 346N), compared to Geary et al. (2013) (~ 517N) participants. While both the Naish et al. and Geary et al. studies employed isometric training, the way in which the isometric load was established was slightly different; the Geary study had participants exert force to resist a manual resistance supplied by the strength and conditioning coach (e.g. the coaches hand was placed on the head and the participant was required to "prevent" the coach from moving the head), while the Naish et al. study had participants exert force by pulling on an immoveable object. Therefore, in the Naish et al. study participants would have been exerting purely isometric force, whereas depending on the amount of movement in the manual resistance, the participants in the Geary et al. study may be exerting eccentric, concentric or isometric force. Slight differences in the way the force was generated in the muscle, along with differences in total load (Geary et al. 3 sets x 10 s holds twice per week and Naish et al. 2-3 sets x 4-12 reps 2-3 sessions per week) may account for differences in neck strength adaptation in these studies.

It is interesting to note that the only non-significant improvement in neck strength in this study (flexion) was also the only exercise that used isometric training, whereas the exercises for the other 3 directions (extension, left and right lateral flexion) used isotonic exercises. The addition of the isometric training in the program in this study was to increase the time under tension of the players and thereby increase hypertrophy and strength adaptation. In hindsight, we speculate that the time under tension in the isometric exercise was probably too long at the start of training (2 sets of 40 s and 30 s in weeks 1 and 2 respectively), which was combined with a relatively light resistance (7.1 ± 2.5% and 10.8 ± 4.0%, mean ± SD of baseline MVC in week 1 and 2 respectively). Such prolonged and relatively light resistance training would allow the muscle to follow the hierarchical order of fibre activation with Type I (slow twitch) muscle fibres being predominantly activated at this intensity (Beltman et al., 2004), which may explain the lack of strength improvement in the flexion direction.

Table 3: Maximal isometric strength change in the rugby players before (pre) and after (post) 6 weeks of neck strength training.

	Control Group			Strength Group				
	Pre (n = 17)	Post (n =17)	Control Group Pre-Post Change (± 95% CL)	Pre (n = 22)	Post (n = 22)	Strength Group Pre-Post Change (± 95% CL)	Between Group Pre-Post Change (± 95% CL) and Clinical Inference	Between Group Effect Size
Flex (kg)	54.9 ± 7.7	54.3 ± 10.9	-0.6 (9.9)	60.8 ± 16.8	67.2 ± 15.7	6.4 (8.4)	7.1 (13.0) unclear	0.57
Ext (kg)	65.9 ± 8.8	63.1 ± 10.8	-2.9 (8.1)	65.9 ± 19.1	76.5 ± 18.1	10.6 (8.9)*	13.5 (14.6)^ likely increased	0.81
LeftFlex (kg)	62.8 ± 10.6	59.2 ± 11.1	-3.6 (8.9)	54.3 ± 14.9	64.2 ± 10.9	9.9 (7.4)*	13.5 (11.3)*^ very likely increased	1.21
RightFlex (kg)	64.4 ± 12.1	60.5 ± 11.8	-3.9 (11.4)	57.6 ± 19.1	67.5 ± 17.1	9.8 (9.4)*	13.8 (14.9)^ Likely increased	0.90

Data are mean ± SD of each group with the difference between groups given as the mean ± 95% confidence interval along with the effect size of between group difference. Flex, flexion; Ext, extension; LeftFlex, left lateral flexion; RightFlex, right lateral flexion
*Statistical significance ($p < 0.05$); ^Clinically substantial change between groups.

Table 4: Maximal isometric strength change in the Forward and Back positions before (pre) and after (post) 6 weeks of neck strength training

	Pre			Post			
	Forward (n = 14)	Back (n = 8)	Between Group Difference (± 95% CL) and Clinical Inference	Forward (n = 14)	Back (n = 8)	Between Group Difference (± 95% CL) and Clinical Inference	Pre-Post Between Group Difference (± 95% CL) and Clinical Inference
Flex (kg)	61.8 ± 18.9	58.9 ± 13.3	-2.9 (12.2) unclear	69.9 ± 17.4	62.8 ± 12.2	-7.2 (12.4) unclear	-4.4 (17.5) unclear
Ext (kg)	67.6 ± 18.7	62.9 ± 20.7	-4.6 (13.8) unclear	80.9 ± 18.2	69.2 ± 16.5	-11.7 (14.0) likely decreased	-7.1 (19.8) unclear
LeftFlex (kg)	56.4 ± 12.5	50.7 ± 18.7	-5.7 (10.9) unclear	64.7 ± 11.4	63.5 ± 10.9	-1.2 (10.5) unclear	-4.4 (15.4) unclear
RightFlex (kg)	55.7 ± 17.4	60.9 ± 22.5	-5.2 (14.1) unclear	70.0 ± 16.6	63.4 ± 18.1	-6.6 (14.3) unclear	-11.9 (20.2) unclear

Data are mean ± SD of each group with the difference between groups given as the mean ± 95% confidence interval. Flex, flexion; Ext, extension; LeftFlex, left lateral flexion; RightFlex, right lateral flexion
*Statistical significance ($p < 0.05$); ^Clinically substantial change between groups.

While the effect of neck strengthening exercises on concussion in sportspeople is controversial (Collins et al., 2014; Eckersley et al., 2019), the effect of such training on reduction in neck pain and injury is more consistent. Training the cervical muscles and deep neck flexors has a beneficial effect on the incidence of neck pain (Äng et al., 2009) and injury (Salmon et al., 2011). Moreover, in a retrospective analysis of professional rugby union players, Naish et al. (2013) reported a significant decrease in the number of match-related cervical spine injuries after a 26-week neck strengthening program. Furthermore, a neck strengthening program, similar to that described in this study, has been found to be effective at reducing neck injuries in rugby players (Hrysomallis, 2016). It is well known that tackling in rugby union is responsible for the most injuries sustained by players (Williams, Trewartha, Kemp, & Stokes, 2013), and that head placement is an important factor in these injuries (Tucker et al., 2017). If improved neck strength helps to reduce the load during impacts (Eckner et al., 2014), or helps to stabilize other muscles (O'Leary, Falla, Hodges, Jull, & Vicenzino, 2007) we speculate that less injury may occur in the head and neck area. However, this theory would need to be corroborated with longitudinal injury statistics before recommendations on the effect of neck strength training on injury could be made.

The substantially higher neck girths in forwards compared to backs (Table 2) is likely to be due to the higher body mass since body mass was moderately correlated to neck girth (r = 0.69). Apart from body mass (and the accompanying body fat and lean body mass) forwards were similar to backs in terms of strength (Table 2) and their adaptation to the neck strength training program. The similarity in response between players indicates that such a program should benefit all players (forwards and backs) equally.

A limitation of the study was low subject numbers which minimized the ability to identify the effect of neck strength training on the various rugby player positions. We were able to look at the overall differences between backs and forwards, barring a larger and more varied sample, we cannot be certain of the effects on specific playing positions (e.g. fullback versus a prop). It is also important to note that the training completed in this study only looked at neck muscles contributing to force production in two planes of movement (frontal and sagittal) and that training muscles which contribute to all neck movement may produce different results.

5. Conclusion

If increasing the neck strength in rugby players is a training goal we would recommend a training program similar to that described in this study. However, we would caution against the use of isometric training for neck strength improvement unless training loads can be adequately measured and adjusted.

Conflict of Interest

The authors declare no conflict of interests.

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