**Supplementary Materials**

**Table 2:** All included studies in the review.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Study ID** | **Study Design &Setting** | **Participant** | **Aim relevant to the review** | **Intervention and control** | **Outcomes/General findings** | **Author's conclusion** | **CASP Total score (%)** |
| Chavarro-Nieto et al.,2021 | Systematic Literature Review  **Setting:**  New Zealand | Male Rugby players  n=1066  Mean sample size: 76  Professional, Sime-professional, amateur, and school-age | To review and summarise the literature investigating neck strength and its potential role in injury incidence, including concussions in Rugby Union players, neck strength measures, and neck strengthening exercises. | **The intervention of the included studies**:  Neck strengthening interventions  Neck strength assessments  **The comparator of the included studies:**  Not indicated | By incorporating neck exercises into their training regimen, professional players have improved neck strength across all directions. In particular, senior elite male players have shown greater strength compared to their younger counterparts. In the sport of Rugby Union, forwards tend to have stronger necks than backs, with a particular emphasis on neck extension. Additionally, forwards tend to have larger necks and cross-sectional areas. However, current research has only been conducted on male participants, and there is little data on the incidence of concussion in relation to neck strength or strengthening strategies among Rugby Union players as a whole. | Although there is limited evidence on the direct connection between neck strength and concussions, strengthening the neck or cervical musculature remains a popular method for preventing head and neck injuries among Rugby Union players. | 3/10  (30%) |
| Elliott et al., 2021 | Systematic Literature Review  **Setting:**  Switzerland | Observational studies: n = 6792 (Male and female high school and university athletes)  Experimental studies:  n= 3953 (male adolescents and adult Rugby players | To evaluate the literature on whether neck exercises decrease the incidence of sport-related head injuries, including concussions and the relationship between neck strength and sport-related head and neck injuries and sports-related concussions. | **Intervention in the included studies**:  Neck exercises are completed either in isolation or as part of a more comprehensive exercise program.  **The comparator of the included studies:**  Not include neck exercises. | Higher neck strength but not deep neck flexor endurance is associated with a lower risk of sustaining a concussion.  However, limited evidence that neck strengthening exercises and greater neck strength may reduce or lower the incidence of sport-related head injuries, including concussions, in adolescent and adult rugby union players. | Incorporating neck exercises into injury reduction programs may decrease the likelihood of head and neck injuries in sports, including concussions. | 2/10  (20%) |
| Attwood et al., 2022 | Randomised controlled Trials (Pilot)  **Setting:**  UK  **Undertaken:**  Mid-July -September  2019 | U18 male Rugby Union Regional age group players  n =28  Age:16.9 ± 0.6 years  ***Intervention***:  n = 15  (Mean ± SD)  Height: 179 ± 7 cm  Body Mass: 87.8 ± 14.0 kg  Neck Circumference: 38.2 ± 2.7 cm  ***Control***:  n = 13  (Mean ± SD)  Height: 181 ± 5 cm  Body Mass:87.9 ± 14.9 kg  Neck circumference: 37.5 ± 2.2 cm | To investigate the effect of  self-resisted neck exercises on neck/cervical muscle strength in U18 male regional age-group rugby union players. | ***Intervention group:***  A trainer-led intervention program involved neck-resisted contractions. Players pushed against their heads using their hands.  **Direction:**  Flexion, Extension, Left and Right-Side flexion  **Protocol:**  1 x 15 seconds of maximum contraction in each direction with 30 seconds of rest  **Frequency:**  Eight weeks (3 times per week)  ***Control group:***  Maintained regular training and did not involve neck strengthening exercise  **Outcome Measure:**  Dynamometer | Neck strength pre and post, 5 weeks neck strength training:  ***Intervention Group***  Pre/Post/SD  **Flexion:** 183.4(36)N/225.8(35.2) N  **Extension**: 270.8(72.9) N/376.3(69)N  **Right Side Flexion:** 185.3(59)N/291.8 (53.3) N  **Left Side Flexion:** 192.1(68.1) N/ 290.1(60.8) N  **Total Neck strength:**  831.6(204.5) N/ 1184 (189.4) N  ***Control Group:***  Pre/Post/SD  **Flexion:** 190.2(35)/222.2(49.6)  **Extension:** 271.3(73.2)/307.2(57.5)  **Right Side Flexion:** 199.5(60.8)/240.5(57)  **Left Side Flexion:** 184.9(41.5)/256.7(40.1)  **Total Neck strength**:  845.9(164.5)/1026.5(155.8)  **Findings:**  Significant increase in total neck strength in the intervention group of 24% (effect size [ES] = 1.2, MD ± 95% CI = 155.9 ± 101.9 N, P = 0.004 (large) compared to the control group. Greater neck strength was associated with fewer head and neck injuries, including concussions. | Incorporating as elf-resisted neck strengthening program performed in isolation or as part of a training programme increased neck/cervical strength in Rugby Union players and could contribute to reducing sports-related head and neck injuries, including concussions. | 5/13 (38%) |
| Deng et al., 2022 | Randomised Controlled Trial  **Setting:**  Australia  **Undertaken:**  December 2019 to February 2020 | 40 Female Elite Athletes  N= 10 (Soccer Players)  N= 30 (Australian football players)  Age: 24.4 ± 5.3 years  Height: 170.0 ± 5.0 cm  Body mass: 67.2 ± 6.3 kg  **Intervention** group: n=20  **Control group:** n=20 | To investigate the efficacy of a 12-week neck strengthening program on isometric neck strength in women's football codes athletes. | Strength and conditioning of the cervical spine:  ***Intervention group:***  Self-directed isometric neck strengthening programme added to standard training (monitored using the Teambuildr App).  **Direction:**  flexion, extension, left and right lateral flexion, left rotation and right rotation  **Protocol:**  3 sets x 10 seconds hold in each plane with 10 seconds rest between sets  **Frequency:**  3 times a week for 12 weeks.  ***Control group:***  Standard strength and conditioning program without the addition of neck-strengthening exercises  **Outcome measure:**  Hand-held dynamometer for strength (assessed pre, mid (Week 7), and post (Week 13) intervention | Neck strength pre and post, 12 weeks of isometric neck strength training  ***Intervention Group:***  Pre- Mid – Post (Mean± SD)  **Flexion**:1.34±0.18/1.36±0.33/1.52±0.24 N/Kg  **Extension**: 1.59±0.32/1.66±0.55/1.84±0.44 N/Kg  **Left Lateral Flexion:** 1.23±0.24/1.33±0.35/1.49±0.30 N/kg  **Right Lateral Flexion**:1.22±0.23/1.37±0.39/1.49±0.28 N/Kg  **Left Rotation**:1.18±0.21/1.30±0.38/1.46±0.23 N/Kg  **Right Rotation:** 1.23±0.20/1.37±0.36/1.49±0.21 N/Kg  ***Control Group***  Pre-Med-Post (Mean± SD)  **Flexion:** 1.44±0.22/1.36±0.29/1.53±0.24 N/Kg  **Extension:** 1.87±0.42/1.78±0.36/2.00±0.31 N/Kg  **Left lateral flexion:** 1.47±0.21/1.45±0.22/1.58±0.18 N/Kg  **Right Lateral Flexion:** 1.48±0.27/1.43±0.20/1.59±0.28 N/Kg  **Left Rotation:** 1.36±0.19/1.37±0.33/1.55±0.27 N/Kg  **Right Rotation:** 1.42±0.17/1.46±0.20/1.53±0.24 N/Kg  **Findings:**  No adverse effects. All strength variables significantly changed throughout the 12 weeks (p < 0.05). No significant difference between groups in isometric neck strength variables except for left lateral flexion (F (1, 38) = 5.064, p = 0.030, η2 p = 0.117). | During the 12-week self-directed isometric neck strengthening program added to formal training, there were no significant improvements in neck strength among elite female athletes. However, both groups did experience improvements in neck strength, circumference, and head-to-neck ratio over the 12-week period. | 6/13 (46%) |
| Peek et al., 2022 | Randomised Controlled Trial  (Pilot trial)  **Setting:**  Australia  **Undertaken:**  June and October 2020 | Adolescent Football Players  Male and female:  n= 52  Ages:12–17 years  ***Experimental:*** n=31  Age: 14.35±0.29 years  Height:1.64± 0.01 m  Weight:53.06±1.69 kg  Years played: 8.51 ±0.40  ***Control:***  n=21Age: 14.95 ± 0.21  Height: 1.69±0.02  Weight: 55.90±2,25 (  Years played:9.67±0.34 | To investigate the effects of the FIFA 11+ training programme that includes neck exercises on isometric neck strength in all planes of motion of the neck/cervical, head impact on purposeful heading and the validity and feasibility of the programme in adolescent football players. | Strength and conditioning of the cervical spine:  ***Intervention group:***  Five weeks of supervised neuromuscular neck strengthening exercises integrated into part 2 of the FIFA 11+ training programme  **Direction:**  Versteegh Roll and Tuck (VRT) head pointed straight ahead and turned each side (flexion, extension, Right and left flexion).  **Protocol:**  1 set x 30 seconds in each direction  **Frequency**:  Three times per week for five weeks  **Control group:**  Part 2 of the FIFA 11+ training programme, no neck exercises (3 times a week for five weeks)  **Outcome measures:**  hand-held dynamometer | Isometric neck strength pre and post, five weeks of neck exercises  ***Intervention Group***  Pre/Post/SD  **Flexors:** 8.44/13.16kg/2.79  **Extension**: 13.67/20.89kg/5.14  **Right Side Flexors:** 8.74/13.70kg/3.26  **Left Side Flexors**: 9.02/13.61kg/3.0  **Composite Neck strength**: 10.37/15.95kg/3.35  ***Control Group:***  Pre/Post/SD  **Flexors:** 13.66/14.81kg/2.84  **Extensors:** 21.54/23.54/3.58  **Right Side Flexors:** 12.67/16.15kg/3.04  **Left Side Flexors**: 13.37/16.42kg/3.52  **Composite Neck strength:** 15.94/18.43kg/3.97  **Findings:**  A significant increase in mean composite neck/cervical strength of 53.8% compared to control of 15.6% (P<0.001, ES= 0.27, 95% CI = 0.12–0.39). A decrease in head impact magnitude during heading in the intervention group −11.8% vs the control group −5.0%. Neck/cervical spine strengthening exercises added with FIFA 11+ were feasible and accepted by coaches and players. | By incorporating neuromuscular neck strengthening exercises into the training program, adolescent football players experienced improved composite neck strength and reduced head impact magnitude during heading. It is recommended to consider including these exercises in part 2 of the FIFA 11+ for this group of athletes, as it can help lower the risk of head injuries during heading. | 5/13 (38%) |
| Wilson et al., 2021 | Cohort study  **Setting:**  Colorado, USA  **Undertaken:**  Not specified | Soccer players  N=83 (male:50; female:33)  ***Experimental Group***  N= 50  Age: 15.1(14.8-15.4) y  Height: 168.9(166,2-171.6) cm  Body Mass: 61.2(58.1-64.2) kg  Neck circumference: 33.1(32.4-33.9) cm  ***Control Group***  N=33  Age: 15.1(14.7-15.5)  Height: 168.6(165.3-172) cm  Body mass: 58.7(54.9-62.5) kg  Neck circumference:32.8(31.9-33.7) | To assess whether a web-based 6-week cervical strengthening exercise program increased cervical spine strength in adolescent soccer players | Strength and conditioning of the cervical spine:  ***Intervention group:***  Unsupervised Web-based cervical muscles exercise program  **Direction:**  Isometric contractions (flexion, extension, left-side flexion, and right-side flexion)  **Protocol:**  4 sets x 10 seconds' hold  **Frequency:**  3-7 times a week for 6 weeks  ***Control group:***  Continue normal preseason conditioning without neck strengthening exercises  **Outcome measure:**  Hand-held dynamometer  pre-post (initial and follow-up) | Neck strength initial – follow-up, 6 weeks neck strength training  ***Intervention Group***  Initial – Follow-up (n=43)  **Flexion:** 128.5 (120–137.7)/ 148.2 (137.9–159.3) N; MD=1.2 (1.1–1.2)  **Extension:** 155.2 (143.3–167.2)/184.3 (173.3–195.3); MD=27.9 (18.4–37.5)  **Left Side Flexion**: 124.8 (115–134.6)/ 150.1 (139.2–161) N; MD=24.1 (15.9–32.4)  **Right Side Flexion:** 122.3 (113.5–131.1)/ 141.4 (131.9–150.9) N; MD= 18.8 (11.6–26.1)  **Neck circumference:** 33.2 (32.5–34)/ 34 (33.1–34.8) N; MD=0.8 (0.5–1.2)  ***Control Group***  Initial – Follow-up ***(n=32)***  **Flexion:** 140.2 (128.1–153.4)/ 132.5 (121.1–145) N; MD= 0.9 (0.9–1)  **Extension**: 182.1 (166.9–197.2)/ 177.7 (167.4–188.1) N; MD= 21.5 (215.8–12.8)  **Left Side Flexion**: 146 (133.6–158.5)/ 146.1 (133.7–158.5) N; MD= 1.9 (27–10.9)  **Right Side Flexion:** 134.9 (122.7–148.4)/ 134 (122.5–146.6) N; MD= 1 (0.9–1.1)  **Neck circumference:**  32.8 (32–33.7)/ 33.7 (32.9–34.4) N; MD= 0.9 (0.5–1.3)  **Findings:**  After adjusting for initial preseason testing values and sex, the intervention group demonstrated increased cervical strength (N) in flexion (24.8 [95% CI: 13.1, 36.6], p, 0.001), extension (16.1 [95% CI: 3.5, 28.6], p = 0.013), **RLF** (12.4 [95% CI: 0.4, 24.4], p = 0.043), and **LLF** (16.9 [95% CI: 5.2, 28.6], p = 0.005) at follow-up testing compared with the control group. | A 6-week web-based cervical strengthening program improves cervical muscular strength in adolescent soccer players and is safe to use outside of a practice setting, which may be helpful when training time is limited. The programme could also be used by researchers and practitioners evaluating the influence on concussion risk and as a means of reducing sport-related head and neck injuries. | 3/10  (30%) |
| Müller et al., 2021 | Quasi-experimental study  **Setting:**  Germany  **Undertaken:**  Not specified | U17 and U19 soccer players  n=27  (Male and female)  Ages: 15 – 18  **Intervention group:** n =14  Height: 1.74± 0.11  Body mass: 64.4±14.7  **Control group**: n=13  Height:1.76 ± 0.09  Body mass:69.0 ±12.9 | To investigate the efficacy of a neck strengthening intervention programme to increase neck muscle strength and to reduce head acceleration during purposeful heading in  youth soccer players. | Strength and conditioning of the cervical spine:  ***Intervention group:***  Neck and trunk resistance training (isometric, dynamic) and perturbation exercises for the neck muscles while isometrically engaging the trunk musculature.  **Direction:**  Isometric holds in each direction (Flexion, Extension and Lateral flexion) added to regular biweekly soccer training  **Protocol:**  15 minutes as part of a warm-up,  1-2 each side x 10-15 seconds head hold (maximum resistance)  **Frequency:**  2 x a week for 14 weeks  ***Control Group*:**  Completed regular soccer  training 2x  a week and no added neck exercises  **Outcome measure:**  Medical exercise therapy machine ("Genius ECO HWS Trainer," Frei AG, Kirchzarten, Germany) | Neck strength pre and post, 14 weeks neck strength training  ***Intervention Group:***  Pre-Post (Mean ± SD)  **Flexion:** 79.5 ± 46.1/ 91.0± 75.55 N  **Extension:** 118.7 ±44.6/135.5 ±51.2 N  **Lateral Flexion:** 100.8 ± 48.4/120.9 ±54.1 N  ***Control Group:***  **Pre-Post** (Mean ± SD)  **Flexion:** 86.5 ± 33.5/ 85.5± 24.3N  **Extension:**  142.2± 50.6/ 142.8± 54.9N  **Lateral Flexion**:  112.0± 39.3/ 117.7± 42.0N  **Findings:**  The neck strengthening intervention programme resulted in moderate to significant strength gains in cervical strength (M(SD): 95.2 (36.5), 145.9 (33.7), 128.4(34.9); ES=0.35–0.48) and reduced head acceleration of 21.5 g, M(SD) = 9.8 (3.4); ES= 0.038; P= 0.301 during purposeful heading in youth soccer players. Lower neck strength (P=0.004) and higher total head accelerations in females compared to males (17.2 ±3.5 g and 13.0 ± 2.3 g; p = 0.003). | Incorporating neck and trunk resistance training into youth soccer players' routines can increase neck strength and reduce head acceleration. Female soccer players, in particular, can benefit from this type of training as a risk reduction strategy. | 5/11  (46%) |
| Hamlin et al., 2020 | Randomised Controlled Trials  **Setting:**  New Zealand  **Undertaken:**  not specified | Male amateur Rugby Union Players (20.1 ± 2.0 yrs. old)  n=39  ***Intervention Group:***  n=22  Height = 183.5±5.3cm,  Weight= 97.6±12.4kg  ***Control group:*** n=17  Height= 181.0±,7.6cm  Weight= 91.0±17.6kg | To explore the effectiveness of a 6-week neck/cervical spine strengthening programme on the neck strength of male amateur Rugby Union players (forwards and backs) that coaches and strength and conditioning practitioners may utilise to assist with the training and development of male amateur rugby union players. | Strength and conditioning of the cervical spine:  ***Intervention group:***  Neck/cervical spine strengthening delivered by a trainer.  **Direction:**  Weighted isometric flexion, weighted head harness isotonic extension,  lateral left and right flexion  **Protocol:**  Extension/ lateral left and right-side flexion:3 x10 reps (week 1-2), 8 reps x 10 (weeks 3-4), 6x 10reps (weeks 5-6)  Flexion: 2 x 40s (week 1), 2 x 30s (week 2), 2 x 20s (week 3), 3 x15s (week 4), 3 x 10s (week 5), 4 x 5s (week 6)  **Frequency:**  3 times a week for 6 weeks  ***Control group:***  Performed standard training but no additional neck-strengthening exercises  **Outcome measures:**  Head harness (Neck Flex) attached to a load cell | Neck strength pre-post, six weeks of neck strength training  ***Intervention Group***  Pre – Post (Mean ± SD)/95%CL  **Flexion:**  60.8±16.8/67.2±15.7kg/6.4  **Extension:**  65.9±19.1/76.5±18.1kg/10.6  **Left Lateral Flexion:** 54.3±14.9/64.2±10.9kg/9.9  **Right Lateral Flexion**: 57.6±19.1/67.5±17.1kg/9.8  ***Control Group:***  Pre – Post (Mean ± SD)/95%CL  **Flexion**:54.9±7.7/54.3± 10.9kg/ -0.6  **Extension:** 65.9±8.8/63.1±10.8kg/-2.9  **Left Lateral Flexion:** 62.8±10.6/59.2±11.1kg/-3.6  **Right Lateral Flexion:** 64.4±12.1/60.5±11.8kg/-3.9  **Findings:**  Neck/cervical strength increased in all planes except for flexion by approximately 12-24% in the intervention group, with no increase in the control group. The intervention will likely increase neck strength regardless of playing position. | Participating in a 6-week neck strengthening intervention program can increase neck strength and improve isometric maximal voluntary contraction strength in male amateur rugby players. This can benefit coaches and practitioners involved in training and developing this group of athletes. | 6/13 (46%) |
| Attwood et al., 2018 | Randomised Controlled Trials (Cluster)  **Setting:**  UK  **Undertaken:** March - June 2015, before the 2015/2016 preseason | Adult male rugby players from 81 clubs  Clusters: Club's team  **All players:** n=673  Age: 25.5 ± 5.6 yrs.  Body Mass: 94.4 ±13.9 kg and  Height: 181.6 ± 7.3 cm  **Intervention:** n=273  **Control:**  n=400 | To evaluate the efficacy of a movement control (injury prevention) exercise program that included neck strengthening in reducing match injuries that resulted in≥8 days' time loss in adult men's community rugby union players. | Strength and conditioning of the cervical spine:  ***Intervention group:***  The exercise program includes proprioception, balance and resistance exercises, including isometric neck strengthening delivered by coaches during training and pre-match.  **Directions:**  Flexion, extension, right and left side flexion  **Protocol:**  15 seconds hold in each 4 directions  **Frequency:**  2–3 times per week for 42 weeks  ***Control group:***  Dynamic stretching and non-targeted resistance exercises  **Outcome Measure:**  Injury burden/incidence rate | **Concussion incidence**  ***Intervention Group*:**  Injuries/ IIR (90% CI)  12/1.2(0.8-1.9)  ***Control Group:***  Injuries/ IIR (90% CI)  33/3.4(2.6-5.5)  **Head and neck incidence**  ***Experimental Group:***  Injuries/ IIR (90% CI)  12/ 1.2 (0.8-1.9)  ***Control Group:***  Injuries/ IIR (90% CI)  35/3.6(2.7-4.8)  **Findings:**  The intervention group is very likely beneficial a 60% reduction in both burdens (RR 0.3; 90% CI 0.2–0.7) and rate reduction ratio (RR) of 0.3 (90% CI 0.2–0.7) for reducing head and neck injury incidence and RR of 0.4 (90% CI 0.2–0.7), 60% in reducing the incidence of concussions. | Male community rugby union players who participated in a neck-strengthening movement control intervention programme experienced a 60% decrease in concussion incidence. Those who followed the programme more closely also saw a significant reduction in injuries. | 4/13 (31%) |
| Hislop et al., 2017 | Randomised Controlled Trial (Cluster)  **Setting:**  UK  **Undertaken:**  August- December 2015 | 40 independent schools' Rugby teams  118 teams n=2,452 players  Males  (schoolboys)  Age: 14 -18 years  ***Intervention group:***  n= 1325  **Age**:16.0 ± 1.2  **Height**: 177.4± 7.3cm  **Body Mass**: 74.7±12.9 kg  ***Control group:***  n= 1127  **Age:**15.9± 1.1yrs  **Height**: 176.6±7.5cm  **Body Mass:** 72.5±13.1 kg | To assess the efficacy of a movement control exercise program that included neck strengthening exercises and the effect of programme dose in reducing injuries that resulted in≥ 24-hour time loss in adolescent rugby players. | Strength and conditioning of the cervical spine:  ***Intervention group:***  Resistance and perturbation training delivered by school coaches and isometric neck strengthening before each training session and match.  **Direction:**  Flexion, extension, right and left side flexion  **Protocol:**  1 x 10 seconds hold in each (4) direction  **Frequency:**  Each training and match warm-up session of approximately 20 weeks.  ***Control group:***  Dynamic stretching and non-targeted exercise, no neck exercises  **Outcome measures:**  Injury burden/incidence rate | Concussion Incidence (1000/hours)  ***Intervention Group:***  IIR (90% CI)  9 (7=11)  ***Control Group:***  IIR (90% CI)  13 (10-15)  Concussion Burden  (1000/hours)  ***Intervention Group***  IIR (90% CI)  260 (252-269)  ***Control Group***  IIR (90% CI)  285 (274-296)  **Findings:**  Intention-to-treat analysis showed unclear effects of the intervention programme on overall match injury incidence (RR)=0.85, 90% CL 0.61 to 1.17, and apparent reductions showed in the intervention programme for concussion incidence (RR=0.71, 0.48 to 1.05). When teams participating completed the program> three times per week, the overall match injury incidence was reduced to 70% (RR=0.28, 0.14 to 0.51) and concussion incidence of RR=0.41, 0.17 to 0.99 in the intervention group compared to the control group. | Performing neck strengthening exercises as part of a preventative movement control program can significantly decrease the number of concussions among schoolboy rugby players. Programme dose demonstrated that participating in this program for over three sessions per week can significantly decrease injuries. | 4/13 (31%) |
| Barret et al., 2015 | Randomised controlled trial (Pilot)  **Setting:**  UK  **Undertaken:**  January - May 2012. | 34 Senior male school-age Rugby players  Age: 16-18 years old  n=34 (16 backs,18 forwards)  ***Intervention group:***  n=17  (8 backs, 9 forwards)  Height: (pre-post) 180.59/181.54 cm  Weight: (pre-post) 88.44/87.59 kg  ***Control group:***  (n=17)  (8 backs, 9 forwards)  Height: (pre-post) 178.81/180.09 cm  Weight: (pre-post) 88.75/84.31kg | To evaluate the efficacy of a tailored neck muscle conditioning program on neck muscle strength,  muscle fatigue, and range of movement of the cervical spine and to highlight that the neck should be regarded as necessary as the other musculoskeletal system in the strength and conditioning program in rugby. | Strength and conditioning of the cervical spine:  ***Intervention Group:***  Sequenced isometric neck training regime with head harness.  **Direction:**  Extension, Flexion, Side flexion, Extension rotation and Flexion rotation  **Protocol:**  6 reps x 4 sets of 50% 1RM, 30 seconds rest between sets  **Frequency:**  Three times per week for six weeks  ***Control group:***  Trained and played, as usual, with no neck exercises  **Outcome measure:**  Wireless load cell,20 Hz with the GS Harness | Neck strength pre-post, six weeks of neck strength training:  ***Intervention Group***  Pre - Post  **Flexion:** 24.60/27.70kg/p=0.175  **Extension:** 38.77/45.65kg/p=0.114  **Flexion with Left Rotation**:21.57/24.44kg/p=0.064  **Flexion with Right Rotation:** 21.86/23.63kg/p=0.972  **Extension with Left Rotation**: 31.42/35.92kg  **Extension with Right Rotation:** 31.64/35.83kg  **Left Lateral flexion**: 33.40/39.95kg/p:0.115  **Right Lateral flexion**: 33.13/39.16kg/p:0.222  ***Control Group:***  Pre - Post  **Flexion**: 22.22/24.99kg/p=0.003  **Extension:**  38.62/41.25kg/p=0.005  **Flexion with Left Rotation**:20.27/21.54kg  **Flexion with Right Rotation**: 19.63/22.32kg  **Extension with Left Rotation**: 30.87/36.02kg  **Extension with Right Rotation**: 31.03/35.22kg  **Left Lateral flexion:** 30.05/35.63kg/p=0.007  **Right Lateral flexion**: 32.32/36.10kg/p=0.017  **Findings:**  The six weeks tailored neck exercise program increases neck strength, particularly neck extension (21.74 kg, M= 15.79 vs13.28 kg, M= 14.72), increases resistance to fatigue and influences right- and left-sided neck muscle balance, and decreases the range of movement of the cervical spine in the intervention group (13.38° vs18.31) compared to the control group. | The tailored isometric neck training regime decreases the range of movement of the cervical spine and  influence neck strength and neck muscle fatigue resistance in rugby players.  In rugby training, the neck or cervical spine should be paid proper attention and given the same level of conditioning focus as the rest of the body. | 6/13 (46%) |
| Geary et al., 2014 | Controlled laboratory study  **Setting:**  Ireland  **Undertaken**:  Not specified | 25 Rugby Union Players  ***Intervention Group*** (Professional): n=15  Age: 19.33±1.29 yrs.  Height: 1.85 ± 0.06 m  Body mass: 95.15 ±13.24 kg)  ***Control Group***  (Semi-professional): n=10  Age: 20.70 ± 1.25 year  Height: 1.85 ± 2.74m  Body mass:101.30 ±12.32 kg  ***Key****:* ***N****= Newton;* ***n*** *= number;* ***m*** *= metre;* ***K*** *=Kilogram;* ***g*** *= gram;* ***CI*** *= Confidence interval;* ***SD*** *= Standard Deviation;* ***MD*** *= Mean Difference;* ***RR*** *= Rate Ratio;* ***IIR****: Injury Incidence Rate;* ***RLF*** *= Right lateral flexion;* ***LLF*** *= Left Lateral Flexion* | To investigate the efficacy of a neck strengthening programme on isometric neck strength in rugby union players. | Strength and conditioning of the cervical spine:  ***Intervention Group:***  Neck strengthening programme  **Direction:**  A professional strength and conditioning coach applies manual pressure to the head in each direction (flexion, extension, left-side flexion, and right-side flexion).  **Protocol:**  3 sets x 10 seconds hold against resistance.  **Frequency:**  2 x a week for 5 weeks  ***Control Group:***  Performed no neck strengthening program.  **Outcome measure:**  Hand-held dynamometer (pre-post intervention/control period) | Neck strength pre and post, 5 weeks neck strength training.  ***Intervention Group:***  Pre-Post (Mean ± SD)  **Flexion**: 334.45 ± 39.31/ 396.05 ± 75.55 N  **Extension**: 606.19 ±97.34/733.88 ±127.16 N  **Left Side Flexion**: 555.56 ± 88.34/657.14 ±122.99 N  **Right Side Flexion**: 570.00 ±106.53/668.00±142.18 N  ***Control Group:***  Pre-Post (Mean ± SD)  **Flexion**: 352.0/ 354.0 N  **Extension**:  594.0/ 594.18 ± 83.03 N  **Left Side Flexion:**  513.0/ 513.25 ±95.23  **Right Side Flexion:**  509.0/ 509.35 ±111.4  **Findings:**  A significant main effect for time (P< 0.05) was observed, intervention group's isometric neck strength significantly increased in all planes (sagittal and frontal). In contrast, no significant improvement in neck strength was observed for the control group participants. | Professional rugby union players who completed a 5-week neck strengthening program experienced significant improvements in their isometric neck strength. Such improvements could positively impact injury prevention, including concussions, as well as screening and rehabilitation for this particular group of athletes. | 5/11  (46%) |