Short Communication

A neck strengthening protocol in adolescent males and females for athletic injury prevention

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Objectives: Sport plays a major role in the physical activity, wellbeing and socialisation of children and adults. However, a growing prevalence of concussions in sports persists, furthermore, that subconcussive forces are responsible for neurodegenerative conditions. Current approaches towards concussion prevention are dependent upon coaching strategies and enforcement by referees, or only attempt to reduce further injury, not prevent initial injury occurring. A growing body of research has shown that strengthening the muscles of the neck might serve to reduce head acceleration, change in velocity and dissipate kinetic energy from concussive and subconcussive forces.

Design: Following ethical approval and parental consent a single arm, pilot study recruited 13 male and 13 female high school students to undertake 8 weeks of neck strengthening exercises 2 $d.wk^{-1}$.

Method: A low-volume, time-efficient approach considered progressive strength training for neck extension, flexion, and right- and left-lateral flexion exercises for a single set to muscular failure.

Results: Strength outcome data was analysed using paired samples t-tests comparing predicted 1-repetition maximum for week 1 and week 8 revealing significant strength improvements for both males and females for all exercises; $p < 0.001$. Effect sizes were very large (2.3-4.3) for all exercises for both males and females.

Conclusions: Participants showed very large increases in neck strength suggesting previous detrained condition and the potential to significantly improve strength using a simple, low volume, resistance training protocol. Athletic training should prioritise health of participants and longevity of career and as such the authors present a neck strengthening protocol with a view to reducing injury risks.

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Key words: chronic traumatic encephalopathy ■ concussion ■ sub-concussive forces ■ strength training ■ adolescent

INTRODUCTION

Advances in physical and physiological training methods for athletes have led to progressive improvements in sports performance. Athletes are now bigger, faster and stronger than ever. However, this increased performance has created an ever growing gap between the physical ability to tackle and the body's physiological capacity to receive impact and trauma in certain orthopaedic structures – notably the head and neck. This has led to an increase in emergency department visits for concussions and other traumatic brain injuries notably in young children (aged 8-13 years) and adolescents (aged 14-19 years) who by 2005 were suffering sports related concussions at a rate of ~4 in 1000 and ~6 in 1000 persons, respectively.[1] Part of this increase might have arisen from improved awareness of concussion resulting in greater reporting of head injuries. However, in a society where we encourage activity in children and where sports plays a role in both physical activity and socialisation we must ensure the health and well-being of these participants.

Governing bodies of sports have developed rule changes in attempt to reduce these risks (e.g. outlawing head to head collision in American football, etc.) and by withdrawing players from the game if they have suspected concussion (e.g. the *'if in doubt; sit them out'* protocol[2-4]). However, in context rule changes must be implemented by coaching strategies and enforced by referees. Furthermore, protocols for suspected concussions only attempt to reduce *further* injury, not prevent the initial injury from occurring. Worryingly, there is a growing body of research to show that repeated sub-concussive forces (e.g. those that do not cause an immediate concussion) to the head and neck can also cause significant medical conditions such as chronic traumatic encephalopathy (CTE) in later life.[5-7] This raises concern beyond more obvious contact sports such as American football, ice hockey, and rugby and suggests that perhaps soccer players, who are subjected to lower impact forces by heading the ball, as well as other athletes, are at considerable risk. A primary purpose of strength and conditioning of all athletes should be the health and wellbeing of the participant and the longevity of their career, with performance improvements being of secondary importance.

Neck Strength

In review, Benson et al.[9] suggested that there was no evidence to support that neck strength increases were related to a decrease in concussion prevalence, however more recently a review of 51 schools and 6,704 high school athletes reported significant associations between smaller neck circumference and weaker overall neck strength[9]. They continue, reporting:

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"Overall neck strength (p<0.001), gender (p<0.001) and sport (p=0.007) were significant predictors of concussion in unadjusted models. After adjusting for gender and sport, overall neck strength remained a significant predictor of concussion (p=0.004). For every one pound increase in neck strength, odds of concussion decreased by 5% (OR = 0.95, 95% CI 0.92-0.98)."

Furthermore, studies dating back to 2007 have used models to support that stronger necks reduce head acceleration, change in velocity and displacement, which ultimately might reduce concussion risks.[10] Notably female soccer players have been shown to have higher head acceleration values compared to males likely as a result of the lower neck strength and muscle mass.[11,12] In addition, data suggests a far greater prevalence of whiplash associated disorders (WAD) in females which, it has been hypothesised, is linked to the weaker neck strength compared to males (32% weaker in flexion, and 20% weaker in extension; $p < 0.001$).[13] Fundamentally it appears that as strength in the head and neck muscles increase, kinetic energy from concussive and sub-concussive forces can be better dissipated. Though no data currently exists to show unequivocally that prospective strengthening of the neck musculature reduces concussion we should consider that, since there are no known risks to strengthening the neck musculature, this is a training intervention that is essential for all athletes. In fact since the benefits likely extend to include reduced risk of whiplash injuries in automobile accidents[13] and improved posture[14]; neck strengthening activities appear vital for all persons irrespective of their sporting/exercise habits.

Regardless of the above, the consensus statement derived from the 4th International Conference on Concussion[15] stated:

"Given that a multi-factorial approach is needed for concussion prevention, well-designed and sport-specific prospective analytical studies of sufficient power are warranted for mouthguards, headgear/helmets, facial protection and neck strength."

Concluding: *"no evidence was provided to suggest an association between neck strength increases and concussion risk reduction"*. However, we feel that delaying neck training until sufficient evidence has demonstrated a reduction in prevalence of concussions and other head and neck related injuries, including CTE, is somewhat irresponsible. Consider that strength and conditioning methods improve physiological markers of performance (e.g. agility, power, strength, speed, vertical jump, etc.) but are not directly proven to enhance specific dynamic sports performance because of the number of associated variables (e.g. changes to opposition, psychological variables, environmental variables, tactical strategies, team performance, etc.) However, we undertake these conditioning techniques with a view to enhancing overall performance, irrespective of underpinning evidence. Since the neck muscles, when trained, might serve to protect athletes from concussion and head trauma, and since there exists no likely risks to strengthening these muscles we propose all athletes, and more likely all persons, should undertake a neck strengthening protocol. As such the authors present a single-arm pilot intervention of adolescent males and females having undertaken 8 weeks of low-volume, neck strengthening exercises.

METHODS

Methodological design

A single arm, 'proof of principle' trial was considered where all participants performed the training protocol. The study design was approved by the relevant ethics committee.

Participants

Twenty-six recreationally active high school students (male; $n = 13$, $m = 16.9 \pm 0.8$years, female; $n = 13$, $m = 17.6 \pm 0.5$years) volunteered, and provided parental informed consent, to undertake a neck strength training protocol 2 $d.wk^{-1}$ for 8 weeks (see Table 1 for participant demographics). Participants performed neck extension, neck flexion, and right- and left-lateral flexion exercises using a plate loaded 4-way neck resistance machine. A familiarisation session was performed prior to any testing/training to establish initial training loads and allow familiarisation of technique and repetition duration. Throughout the training intervention each exercise was performed for a single set to momentary muscular failure (MMF) of 8-15 repetitions using a controlled repetition duration (3 seconds concentric: 5 seconds eccentric) to maintain muscular tension throughout.[16] This equated to a time under load of ~60-120 seconds, and loads were increased for subsequent sessions once participants could perform more than 15 repetitions. This was deemed a safe and appropriate progression based on the nature of the participants and the sensitivity of the muscles being trained.

Statistical Analyses

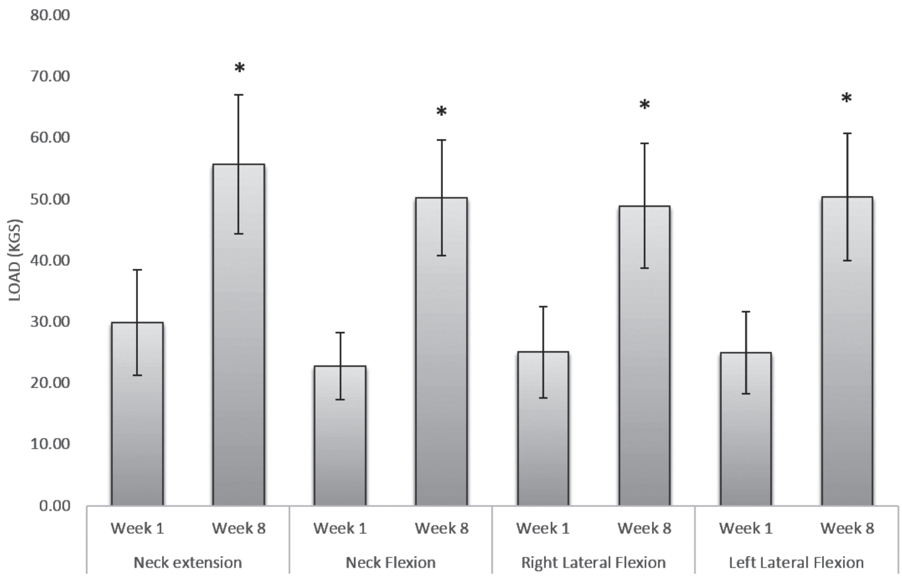
Due to the inherent risks and potential for soreness associated with maximal testing[17], data was recorded as load and repetitions and predicted 1-repetition maximum (1RM) using the Brzycki equation[18] was calculated for week 1 and week 8. This predictive equation shows a high correlation to maximal strength ($r = 0.99$), albeit in an adult population[19]. Data was confirmed for normality of distribution using a Kolmogorov-Smirnov test and analysed using paired samples t-test comparing week 1 to week 8 of the intervention. Pre-testing values were compared between males and females using independent samples t-tests to identify if any differences occurred at baseline. Effect sizes were calculated using Cohen's d[20] for each outcome where an ES of 0.20-0.49 was considered as small, 0.50-0.79 as moderate and ≥ 0.80 as large.

Table 1 Participant demographics

	Male	Female
Age (y)	16.9± 0.8	17.6± 0.5
Stature (cm)	178.2± 4.9	169.7± 8.1
Body mass (kg)	74.5± 11.8	63.5± 13.0
BMI	23.4± 3.2	21.9± 3.8

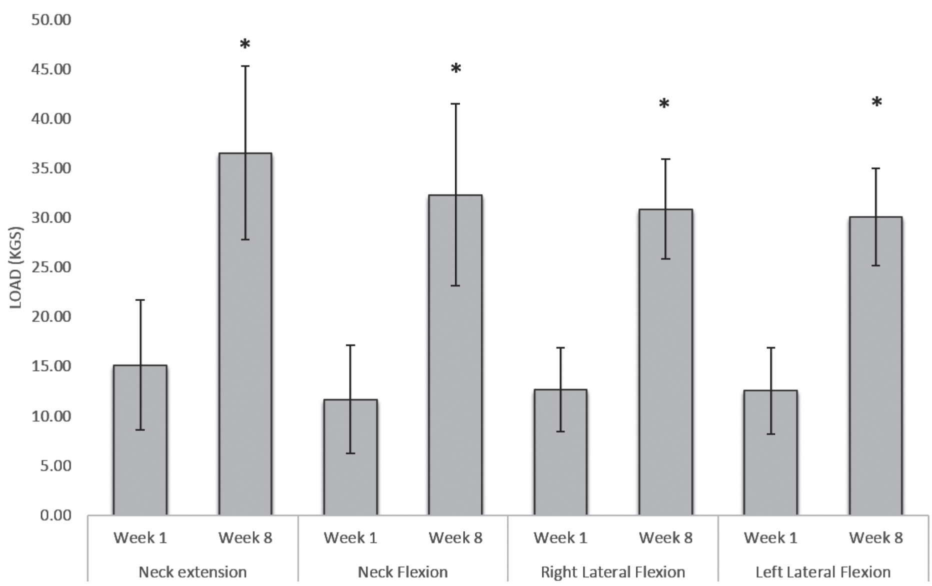
RESULTS

Adherence data revealed that participants performed a mean of 14.6 ± 3.2 and 12.6 ± 2.5 training sessions for males and females, respectively, over the duration of the intervention. Strength outcome analyses revealed the following significant improvements; Males; neck extension from week 1 (mean = 30.2 ± 7.9kgs) to week 8 (mean = 56.7 ± 10.6 kgs); $t(12) = -12.402$, $p < 0.001$, neck flexion from week 1 (mean = 23.3 ± 5.2 kgs) to week 8 (mean = 48.8 ± 9.4 kgs); $t(12) = -8.226$, $p < 0.001$, right lateral flexion from week 1 (mean = 25.5 ± 7.0kgs) to week 8 (mean = 48.2 ± 9.5kgs); $t(12) = -8.422$, $p < 0.001$, left lateral flexion from week 1 (mean = 24.9 ± 6.2kgs) to week 8 (mean = 50.1 ± 10.1kgs); $t(12) = -10.631$, $p < 0.001$ (see figure 1). Females; neck extension from week 1 (mean = 15.5 ± 6.0kgs) to week 8 (mean = 36.8 ± 8.4kgs); $t(12) = -15.448$, $p < 0.001$, neck flexion from week 1 (mean = 11.3 ± ± 5.1kgs) to week 8 (mean = 31.1 ± 9.1kgs); $t(12) = -11.189$, $p < 0.001$, right lateral flexion from week 1 (mean =12.4 ± 3.9kgs) to week 8 (mean = 30.4 ± 5.1kgs); $t(12) = -14.337$, $p < 0.001$, left lateral flexion from week 1 (mean = 12.2 ± 4.1kgs) to week 8 (mean = 29.6 ± 4.9kgs); $t(12) = -13.852$, $p < 0.001$ (see figure 2). Table 2 shows all mean predicted 1RM values for



* Significant difference from week 1 ($p < 0.05$)

Figure 1 Mean Predicted 1RM (± SD) for Males



* Significant difference from week 1 ($p < 0.05$)

Figure 2 Mean Predicted 1RM (± SD) for Females

Table 2 Mean (± SD) Pre and Post intervention Predicted 1RM values (Kg's), *P* values and Effect sizes (ES) for males and females for all exercises

	Males				Females			
	Pre	Post	*P*	ES	Pre	Post	*P*	ES
Neck Extension	30.2 ± 7.9	56.7 ± 10.6	< 0.001	3.4	15.5 ± 6.0	36.8 ± 8.4	< 0.001	4.3
Neck Flexion	23.3 ± 5.2	48.8 ± 9.4	< 0.001	2.3	11.3 ± 5.1	31.1 ± 9.1	< 0.001	3.1
Right Lateral Flexion	25.5 ± 7.0	48.2 ± 9.5	< 0.001	2.3	12.4 ± 3.9	30.4 ± 5.1	< 0.001	4.0
Left Lateral Flexion	24.9 ± 6.2	50.1 ± 10.1	< 0.001	3.0	12.2 ± 4.1	29.6 ± 4.9	< 0.001	3.8

pre and post intervention along with P values and effect sizes (ES).

Independent samples t-tests performed on baseline predicted 1RM revealed the following significant differences between males and females; neck extension (males: mean = 30.2 ± 7.9kgs, females: mean = 15.5 ± 6.0kgs); $t(24) = 5.292$, $p < 0.001$, neck flexion (males: mean = 23.3 ± 5.2kgs, females: mean = 11.3 ± 5.1kgs); $t(24) = 5.952$, $p < 0.001$, right lateral flexion (males: mean = 25.5 ± 7.0kgs, females: mean = 12.4 ± 3.9kgs); $t(24) = 5.915$, $p < 0.001$, and left lateral flexion (males: mean = 24.9 ± 6.2kgs, females: mean = 12.2 ± 4.1kgs); $t(24) = 6.210$, $p < 0.001$.

Relative changes were: males = 94 ± 39%, 121 ± 74%, 100 ± 56%, 108 ± 47% and females = 151 ± 53%, 191 ± 82%, 158 ± 59%, 156 ± 60% for neck extension, neck flexion, right lateral flexion and left lateral flexion, respectively.

DISCUSSION

The present study provides empirical evidence supporting the potential to increase the muscular strength of the neck using an uncomplicated, low-volume, and time-efficient strength training protocol (e.g. single set to MMF 2d.wk-1). Whilst we should not be surprised by strength increases as a result of training the neck musculature, the magnitude of increase suggests a prior detrained condition, and supports the simple protocol demonstrated herein. Previous publications have reported lower values for female's neck strength, compared to males[13], and that this muscular weakness has likely resulted in higher head acceleration values in female soccer players[11,12]. The data presented herein shows pre-intervention neck strength in females to be significantly lower ($p < 0.001$ for all exercises tested) compared to males, supporting previous research. However, relative strength increases were greater in females than males suggesting that the degree of disparity can be reduced as a result of neck strengthening exercises. Previous research has supported that stronger necks reduce head acceleration, change in velocity and displacement which might serve to reduce concussion risks.[10] Furthermore, adjusted models have shown that overall neck strength is a significant predictor of concussion, where a 1lb (0.45Kgs) increase in neck strength produced a 5% decrease in likelihood of concussion[9]. This suggests that the considerable increases in strength demonstrated as a result of this intervention would likely produce meaningful decreases in likelihood of concussion.

We appreciate the present study does not provide evidence of a reduced prevalence of concussion, and only longitudinal studies can show a reduction in occurrence of neurodegenerative conditions. However, in the case of strengthening the muscles of the head and neck; even without unequivocal evidence to support that stronger neck muscles reduce risks of concussion or other head trauma (e.g. CTE) if there is the possibility that strengthening the muscles of the neck can reduce risks, and there exist no known limitations to strengthening the neck, then all strength and conditioning coaches should be encouraging, and all athletes undertaking, a neck strengthening protocol. More so, it is likely the evidence will always be equivocal due to the dynamic and unpredictable nature of sports; a person having performed resistance training for their neck might receive multiple concussions (irrespective of strength) due to the impact velocities and types of impact. In contrast, a person who had never engaged in neck strengthening exercises (irrespective of strength) might never receive a concussion due to the incalculable events occurring in sports. We should also consider the likelihood of disparity in starting neck strength, as exists in other strength variables, due to a large heterogeneity of the population. In addition, it would still require a longitudinal study lasting for decades to determine the prevalence of CTE in persons following a neck training intervention along with a control group, both of which being subjected to repeated concussive and sub-concussive forces. With this in mind the authors of the present piece propose that it is irresponsible, and time might show - negligent, not to apply a neck strengthening intervention to any athletes exposed to potential head trauma in order to attempt to protect athletes and reduce the risk of injury resulting from concussive and subconcussive forces. To date this appears one of few publications considering a neck strengthening protocol and the only study to consider training this musculature in an adolescent group of participants.

CONCLUSION

There is a relative dearth of literature considering neck strengthening protocols and as such the present piece serves to highlight the benefits of training the muscles of the head and neck, potentially with a view to both reducing risks of concussion as well as medical and neurodegenerative conditions arising from sub-concussive brain trauma. In addition the presentation of a simple resistance training protocol which can be performed using resistance machines, or using manually applied resistance will hopefully enlighten strength training practitioners to the simplicity and importance of this exercise procedure. We encourage practitioners at all levels to investigate and apply information regarding strengthening the muscles of the head and neck to attempt to reduce prevalence and risk of concussion and head trauma.

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