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The effectiveness of a neck strengthening program using the NecksLevel ® device in a population of youth female soccer players

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Abstract
Research has shown that neck strengthening exercises can improve neck strength with a direct translation to a reduction in head acceleration during headers. The purpose of this research was to evaluate the use of a novel neck strengthening program on neck strength and girth in a population of youth female soccer players. Using a contemporary neck strengthening device we examined outcomes in isometric neck strength and neck girth in a cohort of 16 female youth (aged 12) soccer players. Paired samples T-tests were conducted to determine differences between pre-and post-training measures. Right Lateral Bending neck strength improved significantly pre- (16.4±5.0 lb.) to post- (17.1±4.4 lb.) training. Flexion, Extension, and Left Lateral Bending neck strength were also improved. These findings underscore the effectiveness of targeted neck-strengthening exercises in enhancing neck strength among female youth soccer athletes and highlight the importance of comprehensive strategies in concussion prevention.

Keywords: Concussion, prevention, football, cervical

Introduction
The global popularity of soccer, particularly among females, offers numerous benefits such as improved fitness, effective exercise, team-building skills, and enhanced mental well-being. However, like many sports, participation in soccer carries inherent risks, with sport-related concussions emerging as a significant concern. In the United States alone, an estimated 3.8 million cases of concussions occur annually, with youth sports contributing a notable 15% of these incidents [10]. Sports with the primary objective of gaining territory and scoring, such as American tackle football, soccer, rugby, and basketball, tend to exhibit higher concussion rates.[9] While male athletes predominantly experience concussions in football, rugby, ice hockey, and wrestling, female athletes face a higher risk in soccer and basketball [10]. Emerging research indicates that females may encounter more prolonged recovery periods and more severe symptoms when compared to their male counterparts, particularly in collision sports [25]. The physiological effects of concussions, including sensorimotor dysfunction and alterations in cerebral blood flow, pose significant risks, especially to the immature brains of youth athletes [10, 22].

Concussion Mitigation Strategies
Past studies have explored various strategies to mitigate the frequency of concussions in sports, including the use of protective equipment like helmets, headgear, and mouthguards.[7] However, evidence regarding their effectiveness in soccer remains limited. A study examining the use of headgear in high school soccer athletes, both male and female, found no difference in incidence, severity, or reduction in sports-related concussions between headgear and no-headgear groups [14]. The study also concluded concussions occurred twice as often in females than in males [14]. Moreover, reliance on equipment could foster a false sense of security, potentially leading to riskier behavior among young athletes [7]. Another mitigation strategy, purposeful heading in soccer, emphasizes the application of Newton's Second Law of Motion

to minimize head acceleration [24].

A program tailored to teaching youth soccer players aged 11-13 years old proper heading techniques, Get AHEAD Safely in Soccer™, has become of interest to the youth soccer coaching establishment [23]. Implementing this program increased neck/torso strength in a cohort of female youth soccer players, though head impact kinematics did not change [23]. However, coaches observed improvements in technique and form in these young female players [23]. Additionally, limited research has explored the potential of neck-strengthening exercises to reduce the incidence of concussions in sports. Studies suggest that athletes with weaker neck muscles may experience greater magnitudes of force during impacts, highlighting the importance of neck strength in mitigating concussion risk [9, 16] For every one-pound increase in isometric neck strength, the risk of concussions decreased by 5%, as the risk of concussion is associated with decreased neck circumference, often found among adolescent female athletes [6]. The utilization of neuromuscular neck exercises, such as the Versteegh roll, has been limited in use but has been shown to reduce head acceleration during heading in adolescent soccer players [17]. The authors recommend the use of neuromuscular neck exercises, especially for youth, to reduce injuries caused by whiplash-type motions by increasing the recruitment of neck muscles, reducing the magnitude of head accelerations on contact, and reducing the pain of heading potentially to mitigate the risk of concussions in adolescent soccer players [17]. Further research is needed, particularly focusing on youth athletes, especially females, to explore additional mitigation strategies against concussions in soccer.

Acknowledging the high incidence of concussions in female youth soccer players and the premise of concussion mitigation via improvements in neck musculature via strength training, this study aimed to address the pressing concerns surrounding concussions among female youth soccer players by implementing an 8-week neck strengthening program. By focusing on targeted exercises and training, we sought to enhance neck strength and stability using a new, novel and commercially available neck strengthening device. Hypothesized improvements in strength have the potential to enhance soccer heading techniques, decrease head impact forces, and preduce concussion risk.

Materials and Methods

Participants

A cohort comprising 16 female youth soccer players participating in the U13 travel soccer division were recruited from a local soccer club during the spring season (February-April 2023). Participants were excluded if they (1) sustained a concussion in the past eight weeks and (2) had a neck injury in the past 6 months; however none of our participants were excluded based on these criteria. This group of soccer players are considered to be playing at the highest level of club soccer participation in the State of Delaware. In aggregate, this group of soccer players had an average of 8.7 years of playing soccer. Subjects were not individually compensated for participating in this research study, although the club team did receive a one-time stipend as financial compensation.

Instrumentation

To evaluate neck strength, a MicroFET2 hand-held dynamometer (Hoggan Industries, Inc., West Jordan, UT, USA) was used. The reliability of the neck strength testing protocol was based on the previous work of Carnevalli *et al.*[2]

The NecksLevel ® Device (NecksLevel ®, Philadelphia, PA) was used in the 8-week neck strengthening program. Described as a "portable, versatile device designed for neck pain relief, neck muscle strengthening, and neck mobility" the device comprises a gliding platform with a head foam pad and four strength bands offering various resistance levels (Figure 1). Participants are provided with a Neoprene headband to prevent slippage while completing the exercise routines.

Fig 1: NecksLevel ® Device (NecksLevel ®, Philadelphia, PA) used for neck strengthening exercises.

Procedures

This study utilized a Quasi-experimental design, employing pretest-posttest methodology using a cohort of young female soccer players. At the outset of the study, participants provided assent forms, while parents/guardians signed consent forms. Approval for the study was granted by the university institutional review board (UDRIB 1899231-1). Each participant then completed a demographic questionnaire covering information such as years of playing soccer, playing position, and concussion history. Baseline measurements of height (centimeters), weight (kilograms), and neck girth (centimeters) (Figure 2) were recorded on each participant.

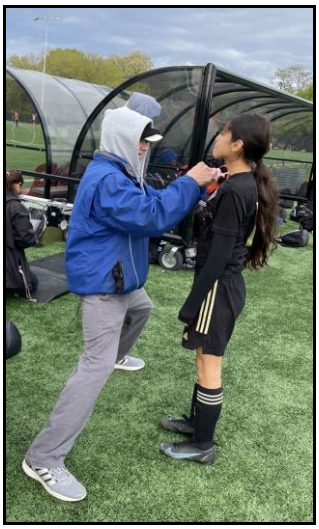
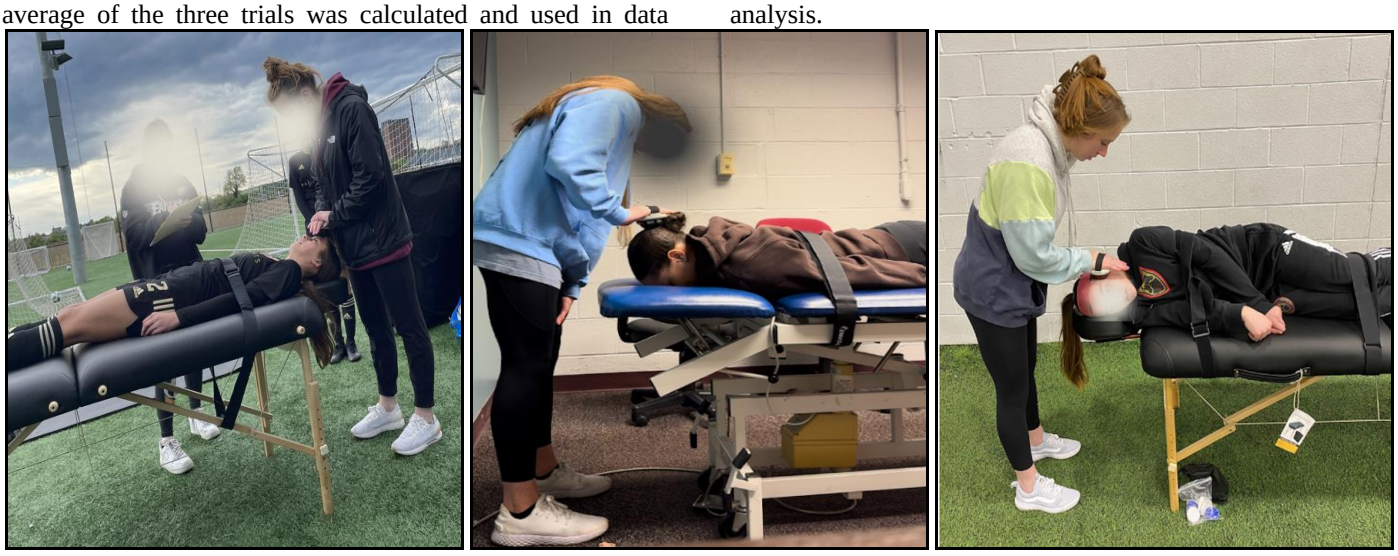


Fig 2: Neck Girth Measurement. Measured just above the thyroid cartilage.

Baseline neck strength measurements involved three movements including isometric flexion, extension, and lateral bending on each side. Participants were positioned on a portable treatment table and secured using Velcro straps placed across the chest and thighs to restrict the use of extremities, ensuring that neck strength was the isolated variable, according to the procedures set forth by Carnevalli *et al.*, and Martins *et al.* (Figure 3) [2, 13]. Participants were instructed to exert maximal force against the device for three seconds across three trials with 30 seconds rest in between. Measurements were recorded in pounds of force, and the

average of the three trials was calculated and used in data analysis.

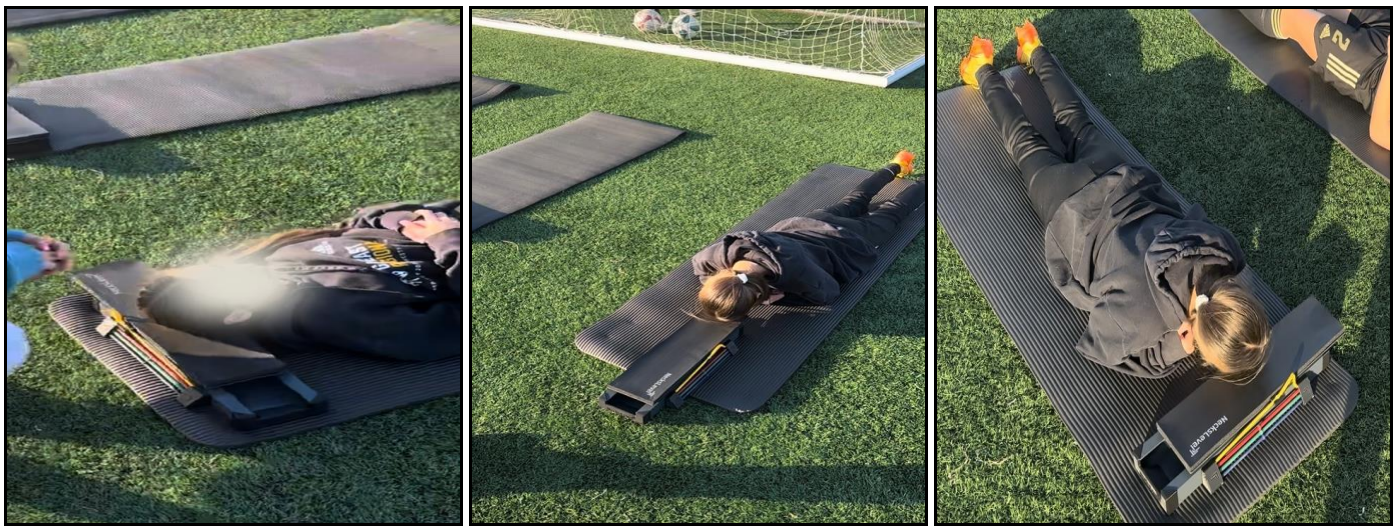


A. B. C.

Fig 3: Neck strength measurement flexion (A), lateral bending (B), and extension (C) using the handheld dynamometer

Following baseline testing, participants underwent two sessions of initial training to familiarize themselves with the NecksLevel® device and in performing the exercises without resistance. Subsequently, participants engaged in an eight-week exercise program, with a frequency of two training sessions per week. To begin each session, participants performed a warm-up routine which involved lying on their back with their head on the device and rotating their head from side to side for 30 seconds. The warm-up routine was repeated twice. Following the warm-up, participants then completed each of the three exercises (Figure 4) involving (1) unilateral isometric holds for neck rotation, (2) prone flexion/extension, and (3) prone rotation; using the prescribed resistance and sets/reps according to the NecksLevel® weekly progression chart (Table 1). For the unilateral iso-hold, an exercise for the neck rotators, the participants laid on their back, loaded the device to one side and then applied pressure down on the device to prevent the device from unloading. The participant applied pressure for the prescribed duration and then repeated the exercise, loading the device to the other side (Figure 4A). The second exercise, prone flexion/extension, required participants to lie on their stomach with the device in a vertical position, and flex and extend their head with their forehead resting on the device (Figure 4B). The third and final exercise, prone rotation, the participants laid on their stomach with the device horizontal, rotating their head from one shoulder to the other (Figure 4C). The neck strengthening routine was performed prior to the start of their soccer practice.

Upon completion of the eight-week neck-strengthening program, the soccer players then participated in post-test assessments using the same approach as the baseline session described above.



A. B. C.

Fig 4: Unilateral Isometric Hold (A), Prone Flexion and Extension (B), and Prone Rotation (C).

Data Analysis

Neck strength (flexion, extension, and lateral bending) and girth were measured pre-and post-training, in a test session conducted before practice began. Paired samples t-tests were utilized to compare means between pre-and post-test measures using SPSS Version 28 (IBM Corp., Armonk, NY).

Results

Sixteen female youth soccer players participated in this study (Table 2). Table 3 includes descriptive statistics for neck strength and girth measures taken pre and post training.

Results demonstrated a statistically significant difference from the pre to post-test in *Right Lateral Bending* (t = -1.767, df [15], p = 0.049). The effect size (Cohen's d = -0.442) suggests a medium-sized difference between the two time periods with the pre-training measures demonstrating lower mean values (16.4±5.0 lbs.) compared to the post-training measures (17.12±4.4 lbs.). Neck *Extension* (t = -1.554, df [15], p = 0.071) approached significance. The effect size (Cohen's d = -0.388) specifies a small to medium-sized difference between the two measurements, with the pre-training measurements exhibiting lower mean values (19.8±6.5 lbs.) compared to the post-training measurements (22.5±6.9 lbs.). Neck *Left Lateral Bending* and *Flexion* strength increased on average from pre- to post-training, but these differences were not considered significant changes. Although there was a slight improvement in neck girth, the difference was not significant.

Utilizing the Dezman *et al.* [5] outcome measures we were also interested in determining strength ratios in our data set. Neck strength ratios of *Flexion* to *Extension* and *Right Lateral Bending* to *Left Lateral Bending* were calculated (Table 4). The ratio of neck *Flexor* to *Extensor* strength shifted from 0.8:1 pre-training to 0.7:1 post-training, while the ratio of neck *Right Lateral Bending* to *Left Lateral Bending* was 1:1 pre-training and increased slightly to 1.1:1 post-training (Table 4).

Table 1: Neck strengthening progression. The lowest resistance indicates the use of the yellow resistance band, and the second lowest resistance indicates the use of the red resistance band.

Week	Sets/Raps	Resistance
1	3 sets of 8 reps or 10s	Lowest Resistance (yellow)
2	3 sets of 8 reps or 10s	Lowest Resistance
3.	3 sets of 12 reps or 15s	Lowest Resistance
4	3 sets of 12 reps or 15s	Lowest Resistance
5	3 sets of 8 reps or 10s	Second Lowest Resistance (red)
6	3 sets of 8 reps or 10s	Second Lowest Resistance
7	3 sets of 12 reps or 15s	Second Lowest Resistance
8	3 sets of 12 reps or 15s	Second Lowest Resistance

Table 2: Subject demographic information including height, weight, age, and playing history. Concussion history reported in 0 concussions indicating no previous concussion history and ≥ 1 indicating 1 or more previous concussions.

Participants (n = 16)	
Age (years)	12.06±0.25
Weight (kg)	51.91±11.63
Height (cm)	159.09±6.43
Years of Playing Soccer	8.66±0.87
Concussion History	
0	11
≥ 1	5

Mean ± Standard Deviation

Table 3: Descriptive Statistics for Neck Girth (cm) and Neck Strength (lb) Measures.

	Pre-Training	Post-Training				
	M±SD	M±SD	p value	Cohen's d	t	df
Neck Girth	30.1±3.0	30.4±2.0	0.278	-0.15	-0.601	15
Flexion	16.6±5.4	16.2±4.4	0.321	0.119	0.475	15
Extension*	19.8±6.5	22.5±6.9	0.071	-0.388	-1.554	15
L Lateral Bending	16.4±4.2	18.5±5.3	0.313	-0.124	-0.497	15
R Lateral Bending*	16.4±5.0	17.1±4.4	0.049	-0.442	-1.767	15

Table 4: Comparison of Ratios (Means ± SD): Strength of Opposing Muscle Groups. Neck Flexion to Neck Extension and Right Lateral Bending (RLB) to Left Lateral Bending (LLB).

	Pre-Training	Post-Training
Flexion: Extension	0.86±0.18 (0.8:1)	0.75±0.16 (0.7:1)
RLB: LLB	1.03±0.17 (1:1)	1.09±0.21 (1.1:1

Discussion

The global popularity of soccer is undeniable; however, the heightened risk of concussions within the sport is a major concern for athletes of all genders. Equally concerning is the elevated twofold risk of concussion faced by female soccer players. Despite research on sport-related concussion mitigation strategies over the past 20 years, including interventions targeting neck strengthening activities, there remains a noticeable gap in interventions specifically tailored to youth soccer players. Thus, this study aimed to address this deficit by implementing an 8-week neck strengthening program designed to target an area of promise for mitigation strategies surrounding concussions in female youth soccer athletes. By focusing on this demographic and employing targeted intervention strategies, our findings contribute to the evolving body of literature aimed at developing and enhancing concussion prevention measures within the sport.

The primary finding of our study revealed improvement in neck strength, as measured by handheld dynamometry following eight weeks of targeted neck strengthening exercise. Notably, a significant improvement was observed in *Right Lateral Bending* neck strength and a trend toward significance in neck *Extension* strength. These outcomes suggest the involvement of neuromuscular mechanisms in driving the observed increases in neck strength. Muscle strength increases achieved between 8-12 weeks are largely attributed to neural adaptations, which include enhancements in neural plasticity and rapid myelination, commonly occurring during prepuberty [21]. Common neuromuscular adaptations resulting from strength training include motor unit recruitment and firing frequency [21]. The eight-week duration

of our intervention likely initiated a process of neuromuscular junction reconstruction, leading to the observed changes. The program was conducted over eight weeks, primarily due to the time constraints imposed by the clubs' spring soccer season timeline. Extending the program to 10-12 weeks has the potential to further enhance strength gains and allow for these gains to be sustained over time. The observed slight improvement in neck girth may stem from the suggested hypertrophic adaptations within the neck musculature, indicative of augmented muscle mass and structural enhancements. We contend that an additional 2-4 weeks of targeted neck strengthening would have likely pushed these differences to be more pronounced and significant.

In this study, a significant improvement was observed in Right Lateral Bending neck strength from pre-training (16.4±5.0 lb.) to post-training (17.1±4.4 lb.). When examining each participant, it was observed that the majority experienced increases in right lateral bending and extension, while there were indifferences across the neck *Flexion*, *Left Lateral Bending*, and *girth* measures. Our findings align with Le Flao *et al*. [11] whose investigation into the effects of a 16-week neck strengthening program on young soccer athletes demonstrated notable enhancements in neck strength among male and female youth soccer players. Notably, females exhibited more substantial gains in extension and flexion strength compared to males [11]. Similarly, Mansell *et al*.[12] noted increases in neck circumference and extensor strength exclusively in college-aged females following an 8-week training regimen, with no corresponding effects observed in males. Additionally, a study by Waring and colleagues investigating the effects of a neck strengthening program on purposeful heading in soccer observed strength gains in the anterior direction for both the control and experimental groups [26]. However, the experimental group demonstrated specific increases in strength for right and left anterolateral directions, while no enhancements were noted in rotational or posterolateral strength [26]. This discrepancy could be attributed to the lack of emphasis on exercises targeting these movements, as they are not directly implicated in purposeful heading [26]. Furthermore, a study by Collins *et al*. examining flexion, extension, and lateral flexion focused on a population of high school athletes participating in football, soccer, and basketball [3]. Findings from this study concluded that female soccer players were at the highest risk of concussion [3]. Interestingly, it was noted that athletes who experienced concussions had on average less neck strength than the non-concussed athletes [3]. Similarly, it was observed that a smaller mean neck circumference was associated with concussion.[3] This suggests that neck strength and neck girth could serve as significant predictors for concussions, and therefore, athletes with lower neck strength could potentially benefit from neck strengthening programs [3].

The Caccese *et al*. study investigating the relationship between neck size, neck strength, and the prediction of linear and rotational acceleration during purposeful heading in soccer concluded that athletes with smaller neck size and lower neck strength may face an increased risk of experiencing greater head acceleration, and consequently, a higher susceptibility to concussions [1]. Additionally, in terms of rotational acceleration, there is a suggested link with muscle-neck symmetry among female soccer players [5, 8] This symmetry could be linked to purposeful heading techniques by stabilizing co-contracting flexors and extensors in the neck [8, 16]. The ratio of flexor to extensor muscles might contribute to muscle imbalances, leading to increased head accelerations in soccer, and consequently heightening the risk of injuries [5]. This may also be true in assessing left and right lateral bending. Based on our findings, the average ratio of neck *Flexor* to *Extensor* strength shifted from 0.8:1 pre-training to 0.7:1 post-training. In contrast, the ratio of neck *Right Lateral Bending* to *Left Lateral Bending* remained relatively stable at 1:1 pre-training and 1.1:1 post-training. These results line up with previous studies indicating that neck flexors tend to be weaker than neck extensors, potentially contributing to increased head accelerations observed in soccer [5, 15]. Further explorations of the role of neck strength asymmetries are warranted to evaluate their influence on reducing the incidence of concussions.

Our findings offer *some* support to the hypothesis that targeted neck-strengthening exercises can elicit improvements in neck strength and girth, mediated by neuromuscular mechanisms and muscular adaptations. However, it is essential to recognize that neck strength alone may not suffice to mitigate the risk of sports-related concussions, especially in female soccer players. As highlighted by Garrett *et al*. (2023), adequate neuromuscular control and high-rate force development are equally important. Therefore, integrating neuromuscular control exercises into neck strength training regimens may aid in reducing injuries stemming from whiplash-type motions. These exercises can enhance a player's ability to recruit neck muscles, thereby potentially minimizing head acceleration upon contact.[17] Combining neuromuscular exercises with neck strengthening exercises, may help to create a synergistic approach to mitigate sport-related concussion risk and safeguard the long-term well-being of young soccer players. This integrated strategy aligns with existing research and underscores the importance of multifaceted interventions in sport-related concussion prevention [9, 17]. Moreover, while previous studies have reported increased isometric neck strength and girth in both male and female collegiate soccer players, our study contributes novel insights by examining a previously understudied population of youth female soccer players using a contemporary neck-specific strengthening device [12]. Our research thus expands the scope of understanding and emphasizes the importance of addressing concussion risks in female youth athletes.

Our study highlights the importance of implementing targeted neck strengthening programs as a proactive measure to reduce concussion risk among female youth soccer players. Policymakers in sports organizations may consider integrating such programs into concussion prevention protocols to prioritize player safety. Coaches can use our findings to develop and implement evidence-based training protocols aimed at improving neck strength among youth soccer athletes. By incorporating targeted exercises into regular training regimens, the neuromuscular stability of players can be enhanced, potentially reducing the likelihood and severity of sport-related concussive events.

Limitations

The sample utilized in this study consisted of one U13 girls' team from the Mid-Atlantic region of the United States. It is important to note that this sample may not be fully representative of female soccer players aged 13 and younger globally, as the sample represents only a specific demographic within a particular geographic region. Additionally, while our efforts were made to minimize inconsistencies (using previously published methodology) such as having the same individual (EO) perform both pre-

and post-measurements and attention toward stabilizing the participants on a treatment table, inherent limitations in our testing procedures remained. One notable limitation is the potential for inaccuracies introduced by hand-held dynamometry, which can vary based on the strength of the operator in opposing the participant's strength. Furthermore, the results of this study, particularly regarding participant height and weight, suggest that some individuals within the sample may not have yet reached full maturation. This implies that the observed outcomes may be influenced by short-term neurological adaptations specific to this stage of human development. Therefore, it is crucial to interpret these findings within the context of the specific sample and methodologies employed in this study. While the results contribute to our understanding of neck strength, they should not be considered definitive or universally applicable to all individuals in the target age group. Rather, they represent an additional block in the ongoing formation of knowledge within this particular area, highlighting the need for further research to corroborate and expand upon these findings.

Our study emphasizes the need for ongoing research and monitoring to further refine and optimize concussion prevention strategies in youth soccer. Continued research should focus on several ideas that build upon the current findings. It is recommended to implement the neck strengthening program over a 10 to 12-week period to provide insights into the sustained benefits on the neuromuscular system and further enhancements in neck strength, contributing to long-term injury prevention strategies. To enhance the accuracy of neck strength measurements, researchers should consider employing a more precise and reliable device such as the VALD Performance ForceFrame (VALD Performance, Charlotte, NC). Further research among youth, specifically the female population, is imperative to address and mitigate the prevalence of concussions in soccer. Continuous monitoring throughout an entire season should be considered to thoroughly evaluate the efficacy of neck strength in mitigating concussive events. By systematically investigating these aspects, researchers will be able to contribute to the advancement of sport-related concussion prevention strategies in soccer, particularly among young female athletes.

Conclusion

In conclusion, our study reveals significant improvements in *Right Lateral Bending* neck strength following the 8-week targeted neck strengthening program, with neck *Extension* demonstrating a trend toward significance. While neck *Left Lateral Bending*, *Flexion*, and *Girth* increased on average post-testing, these changes were not statistically significant. These findings underscore the effectiveness of targeted neck strengthening exercises in enhancing specific aspects of neck strength among female youth soccer athletes, suggesting potential benefits for concussion prevention. However, the lack of significant changes in certain parameters highlights the complexity of neuromuscular adaptations and emphasizes the need for comprehensive strategies integrating both neck strengthening and neuromuscular control exercises to decrease concussion risks in this population. Further investigation with a larger cohort is necessary to confirm these results and enhance concussion prevention methods in youth soccer.

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Declaration of Interest Statement

The authors report there are no competing interests to declare.

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