COLLEGIATE AND HIGH SCHOOL ATHLETE NECK STRENGTH IN NEUTRAL AND ROTATED POSTURES

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ABSTRACT

Hildenbrand, KJ and Vasavada, AN. Collegiate and high school athlete neck strength in neutral and rotated postures. J Strength Cond Res 27(11): 3173–3182, 2013—A knowledge of neck strength is important for developing conditioning protocols and for evaluating the relationship between neck strength and head and neck injury, but very few studies have examined neck strength in relationship to athletic participation. The purpose of this study was to quantify isometric neck strength in collegiate and high school athletes. We hypothesized that (a) male athletes would have significantly greater neck strength than females; (b) collegiate athletes would be significantly stronger than high school athletes; and (c) neck strength would vary significantly with head posture. A total of 149 subjects participated (77 men and 72 women; 90 college and 59 high school level). Flexion, extension, and lateral flexion neck strength were measured in neutral and rotated head and neck postures. Neck strength varied significantly according to participants’ sex, age, and posture (p < 0.05). Male college students were stronger than those in all other groups (female college students, male high school students, and female high school students). The average female neck strength was 61, 54, and 56% of the average male neck strength for extension, flexion, and lateral flexion, respectively. High school athletes’ neck strength was 75, 68, and 65% of collegiate athletes’ neck strength for extension, flexion, and lateral flexion, respectively. On average, neck strength was the greatest for extension compared with other force directions. The subjects showed large variation in neck strength with posture, but in general, there were no consistent trends among the subjects. This finding suggests that those whose neck strength was considerably lower in nonneutral postures may consider training to increase strength in rotated postures. These data provide important baseline information for future studies evaluating injury risk or training protocols.

KEY WORDS isometric, cervical musculature, MCU, concussion

INTRODUCTION

A knowledge of neck strength is important for understanding the biomechanics of muscle function and the relationship to injury. Strength coaches, therapists, and athletic trainers often recommend strengthening exercises to improve performance or to relieve pain symptoms, but without baseline measures and normative data for appropriate populations, it is difficult to develop neck-strengthening protocols. Athletes may not have similar neck strength measurements as the general population because of extensive training programs and demands based upon sport.

Neck muscle strength has been shown to be a critical factor in the stability of the spine (24), and head and neck injuries are especially prevalent in high impact sporting activities. It has been speculated recently that the strength of the cervical muscles may play a role in the incidence of concussion (12). This is based on the underlying principle that as athletes may tense their neck muscles with an impending collision, they will increase their ability to absorb the impact with their head, neck, and torso (21). It is speculated that those with strong musculature would be better able to absorb the impact forces and thus reduce the incidence of potential concussive forces. A baseline assessment of athletes’ neck strength is needed before a relationship between neck strength and injury can inform strength coaches and athletic trainers in the development of protocols to improve strength and decrease injury.

Recent studies using the head impact telemetry system have found that impacts occur in a wide variety of directions (3,4,12,21). Research focused on football examined the location and magnitude of impacts based on level of play (high school vs. college) and position (offensive line, defensive line, quarterback, etc.). The data show that concussive impacts are associated with a wide range of linear and angular accelerations. However, no consistent threshold for injury exists, and
impacts that result in concussions are not directionally uniform. Impacts have been recorded on the front, back, side, and top of the head (4), which provides the rationale that neck strength in a variety of directions (i.e., flexion, extension, lateral flexion) may play a role in absorbing impacts.

Although data have been recorded about the location and direction of impacts resulting in concussion, to our knowledge, there are no data about head and neck posture at the time of impact. Studies of whiplash injury have shown that a rotated head posture at the time of impact is linked to increased severity of injury (26). If rotated head postures occur at the time of concussion, this could also result in altered neck biomechanics, such as strength, stiffness, and kinematics. Therefore, strength in rotated postures may also be an important consideration in the protocol development for increasing neck strength.

It is also reasonable to consider that age would play a factor in neck strength, with adolescents’ musculoskeletal maturity still developing. To our knowledge, only 1 research group has examined neck strength in children and adolescents (18,31). This study found that flexion, extension, and lateral flexion neck strength increased with age according to a second-order polynomial relationship (31). Further, sex differences in neck strength were not seen in children ages 6–11 years, but significant differences begin to develop in the age group 12–17 and are much stronger in those aged 18–23 years (18).

Most previous research has suggested that normative data on neck strength of both sexes and different age groups are important to establish reference values for comparative evaluation (7,14,20). This is especially true in the athletic population, as the questions of neck strength and incidence of concussion continue to grow. Most previous research on neck strength has focused on flexion and extension strength in sagittal plane postures, and few studies have examined lateral flexion neck strength in the neutral posture, but no previous studies have examined flexion, extension, or lateral flexion strength in rotated postures. Muscle weakness in different force directions and head postures may result in decreased ability to stabilize the cervical spine. With the lack of normative data, it is difficult to determine sound protocols for strength development.

Very few studies have examined neck strength in relationship to athletic participation. The purpose of this study was to evaluate isometric neck strength of collegiate and high school athletes in a variety of head postures and force directions. Specifically, flexion, extension, and lateral flexion strength were examined with the head in neutral posture and rotated 25 and 45°. We hypothesized that (a) male athletes would have significantly greater neck strength than females did; (b) collegiate athletes would be significantly stronger than high school athletes; and (c) neck strength would vary significantly with head posture.

**METHODS**

**Experimental Approach to the Problem**

This study was designed to examine the differences in isometric neck strength between college and high school athletes in a variety of head postures and force directions. Specifically, flexion, extension, and lateral flexion strength were examined with the head in neutral posture and rotated 25 and 45°. We hypothesized that (a) male athletes would have significantly greater neck strength than females did; (b) collegiate athletes would be significantly stronger than high school athletes; and (c) neck strength would vary significantly with head posture.

**Table 1. Subject demographic data (presented are mean ± SD and range [minimum–maximum]).**

<table>
<thead>
<tr>
<th>Number of subjects</th>
<th>Male college</th>
<th>Female college</th>
<th>Male high school</th>
<th>Female high school</th>
</tr>
</thead>
<tbody>
<tr>
<td>47</td>
<td>43</td>
<td>29</td>
<td>30</td>
<td>29</td>
</tr>
<tr>
<td>Age (y)</td>
<td>20.0 (±1.3)†</td>
<td>19.8 (±1.4)†</td>
<td>15.2 (±1.1)§</td>
<td>15.5 (±0.8)§</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.88 (±0.08)‡</td>
<td>1.78 (±0.10)‡</td>
<td>1.78 (±0.10)‡</td>
<td>1.64 (±0.08)‡</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>103.5 (±17.0)§</td>
<td>74.8 (±9.2)§</td>
<td>68.7 (±9.8)§</td>
<td>55.8 (±5.5)§</td>
</tr>
<tr>
<td>Sport</td>
<td>44 Football</td>
<td>24 Basketball</td>
<td>24 Football</td>
<td>8 Basketball</td>
</tr>
<tr>
<td></td>
<td>4 Basketball</td>
<td>4 Soccer</td>
<td>4 Wrestling</td>
<td></td>
</tr>
</tbody>
</table>

*Significantly different from male high school. (Statistical significance: *p* < 0.05, 2-factor analysis of variance.)

†Significantly different from female high school. (Statistical significance: *p* < 0.05, 2-factor analysis of variance.)

§Significantly different from male college. (Statistical significance: *p* < 0.05, 2-factor analysis of variance.)

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athletes (age effect) and between male and female athletes (sex effect). For each athlete, neck strength was measured in neutral and head-rotated postures to examine whether neck strength varied significantly with posture. Strength was measured in different directions (extension, flexion, and lateral flexion), because injurious impacts may occur in a variety of directions and head postures.

**Subjects**

The participants were recruited from a local area high school and a Division 1 collegiate program. High school participants were recruited from men’s football, wrestling, soccer, and basketball, and women’s soccer and basketball. Collegiate athletes participated in football, basketball (men’s and women’s) and women’s crew. Each participant or if a minor, their parent or guardian signed a written informed consent form, and the study was approved through the university’s Institutional Review Board and the school board for high school students. A total of 149 subjects participated (77 male and 72 female; 90 college and 59 high school level; Table 1). The age of high school students ranged from 14 to 17 years, and the age of college students was 17–23 years.

**Procedures**

Isometric neck strength was measured using a Multi-Cervical Unit (Figure 1; MCU, BTE Technologies, Hanover, MD, USA). The unit is designed to measure flexion, extension, and right and left lateral flexion strength with the head in neutral and rotated postures. The device is equipped with a chair that has an adjustable seat height, lumbar support, and a chest and shoulder restraint system to isolate neck musculature. A head halo system is used to safely control the subject’s head placement in different postures. The subjects self-selected a neutral head posture; the halo was secured at the beginning of the test, and each neutral posture and rotated posture were performed in the same secured location. A load cell within the halo measured isometric strength. Several previous studies have used the MCU, and it has been demonstrated to be an accurate and reliable measurement of neck isometric strength (6–8,28).

During isometric neck strength measurement, each participant sat comfortably upright in the adjustable chair, with chest and shoulders secure within the restraint system and the adjustable head halo secured comfortably to the head. The participant was instructed in the proper way to perform each isometric contraction with force applied to the load cell for flexion, extension, and lateral flexion.

Isometric strength measurements were taken following the Melbourne Protocol, in which strength is measured in 4 directions (flexion, extension, and left and right lateral flexion) in a specific order (15). Flexion strength was...
<table>
<thead>
<tr>
<th>Posture</th>
<th>Male college</th>
<th>Female college</th>
<th>Male high school</th>
<th>Female high school</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Extension</strong></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Neutral</td>
<td>158.2 (±62.1) [44.0–309.1]</td>
<td>89.6 (±23.4) [31.1–133.4]</td>
<td>108.6 (±31.9) [53.4–172.6]</td>
<td>82.0 (±21.5) [28.9–131.2]</td>
</tr>
<tr>
<td>Left rotated 25°</td>
<td>147.7 (±56.2) [48.0–267.8]</td>
<td>80.8 (±24.3) [28.9–132.1]</td>
<td>99.8 (±27.7) [46.3–145.0]</td>
<td>73.3 (±20.8) [19.6–131.7]</td>
</tr>
<tr>
<td>Right rotated 25°</td>
<td>146.6 (±58.1) [49.8–260.7]</td>
<td>81.9 (±25.9) [29.4–141.9]</td>
<td>98.6 (±35.3) [42.7–193.0]</td>
<td>71.9 (±22.7) [21.8–142.3]</td>
</tr>
<tr>
<td>Left rotated 45°</td>
<td>128.2 (±48.6) [44.5–244.6]</td>
<td>73.0 (±23.5) [23.6–129.4]</td>
<td>92.2 (±32.1) [37.4–181.0]</td>
<td>66.7 (±24.2) [17.4–146.3]</td>
</tr>
<tr>
<td>Right rotated 45°</td>
<td>133.8 (±54.5) [44.9–282.9]</td>
<td>72.3 (±25.1) [24.0–145.5]</td>
<td>88.8 (±30.4) [40.0–147.2]</td>
<td>63.2 (±21.8) [20.9–135.2]</td>
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<tr>
<td><strong>Flexion</strong></td>
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<tr>
<td>Neutral</td>
<td>125.3 (±59.1) [28.5–292.2]</td>
<td>55.7 (±19.9) [24.5–112.1]</td>
<td>73.8 (±29.7) [25.8–145.5]</td>
<td>55.9 (±19.6) [21.8–105.0]</td>
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<tr>
<td>Left rotated 25°</td>
<td>120.6 (±52.5) [47.6–267.8]</td>
<td>56.5 (±19.2) [20.5–103.6]</td>
<td>68.3 (±25.1) [29.4–134.8]</td>
<td>53.8 (±16.4) [32.9–101.9]</td>
</tr>
<tr>
<td>Right rotated 25°</td>
<td>124.9 (±53.9) [32.5–282.9]</td>
<td>55.0 (±18.9) [18.7–112.5]</td>
<td>70.3 (±25.5) [24.5–120.1]</td>
<td>52.7 (±16.8) [28.9–101.0]</td>
</tr>
<tr>
<td>Left rotated 45°</td>
<td>113.4 (±45.3) [38.7–233.5]</td>
<td>54.4 (±19.0) [20.5–104.1]</td>
<td>65.4 (±20.0) [28.9–112.1]</td>
<td>49.7 (±15.3) [28.9–99.6]</td>
</tr>
<tr>
<td>Right rotated 45°</td>
<td>118.6 (±49.5) [38.3–243.8]</td>
<td>53.2 (±16.8) [20.0–94.3]</td>
<td>66.1 (±23.0) [32.0–132.1]</td>
<td>48.9 (±16.4) [24.0–92.1]</td>
</tr>
<tr>
<td><strong>Left lateral flexion</strong></td>
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<tr>
<td>Neutral</td>
<td>112.8 (±43.8) [38.7–219.7]</td>
<td>59.6 (±19.2) [14.7–113.0]</td>
<td>65.6 (±22.9) [24.9–113.9]</td>
<td>48.6 (±19.3) [20.0–103.6]</td>
</tr>
<tr>
<td>Left rotated 25°</td>
<td>117.6 (±48.7) [32.0–231.3]</td>
<td>58.0 (±20.4) [13.3–105.9]</td>
<td>68.1 (±23.9) [34.3–136.1]</td>
<td>49.9 (±19.1) [20.9–98.8]</td>
</tr>
<tr>
<td>Left rotated 45°</td>
<td>127.2 (±55.1) [41.4–290.5]</td>
<td>61.2 (±20.2) [27.6–133.4]</td>
<td>73.4 (±25.1) [31.1–138.8]</td>
<td>53.6 (±19.0) [25.8–101.9]</td>
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<tr>
<td><strong>Right lateral flexion</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Neutral</td>
<td>115.4 (±45.0) [44.0–204.6]</td>
<td>60.6 (±23.2) [19.1–130.3]</td>
<td>62.5 (±21.1) [18.2–100.5]</td>
<td>47.2 (±20.4) [16.5–118.3]</td>
</tr>
<tr>
<td>Right rotated 25°</td>
<td>119.2 (±47.7) [40.0–258.4]</td>
<td>58.3 (±24.3) [21.8–124.1]</td>
<td>67.5 (±25.8) [30.7–155.2]</td>
<td>48.0 (±17.4) [27.1–103.6]</td>
</tr>
<tr>
<td>Right rotated 45°</td>
<td>129.9 (±54.0) [33.8–235.7]</td>
<td>62.6 (±22.3) [24.0–120.5]</td>
<td>73.7 (±28.9) [34.3–150.8]</td>
<td>50.0 (±17.6) [25.8–101.4]</td>
</tr>
</tbody>
</table>

*Data presented are mean (±SD) and range [minimum–maximum].
measured first in neutral, then with the subject's head in
a rotated posture of 25° left and right, then the last measure-
ment was taken with the head rotated to 45° left and right
(Figure 2). Next the isometric extension strength measure-
ments were taken in neutral, 25° right and left rotated fol-
lowed by 45° of right and left rotation. Lateral flexion
strength was only measured in neutral and to the ipsilateral
rotated side (e.g., in the 25° right rotated posture, right lateral
flexion strength was measured, but not left lateral flexion
strength). This resulted in 16 unique measurements of neck
strength for each participant.

For each combination of force direction (flexion, extension,
right and left lateral flexion) and head posture (neutral or
rotated), the participant was instructed and encouraged to
perform 3 consecutive maximum exertions of 3 seconds each
with a 10-second rest between trials. Peak force was calculated
during each trial, and the average of 3 trials was considered to
be the subject's isometric neck strength. Less than 10% covari-
ance among trials was considered an accurate assessment of
neck isometric strength. If >10% covariance existed among
trials, additional trials were performed until the covariance
was <10% in 3 trials. There was a 2-minute rest period
between changes in force direction or posture.

Statistical Analyses
Each force direction (flexion, extension, right and left lateral
flexion) was analyzed separately using multivariate analy-
sis of variance, with factors as sex, age (college or high
school), and posture, which was a repeated measure on all
subjects. Neck strength was also presented relative to body
weight to examine the differences between age and gender
on a normalized parameter. Post hoc pairwise comparisons
were performed if the results of analysis of variance were sig-
nificant at the $p \leq 0.05$ level. Data were also tested for sym-
metry using paired $t$-tests: flexion and extension strength was
compared at the 25° left vs. right and at the 45° left vs. right
rotated postures; and left and right lateral flexion strength
was compared at neutral, and at the 25° and 45° ipsilaterally
rotated postures (i.e., left lateral flexion strength in 25° left
rotated vs. right lateral flexion strength in 25° right rotated

![Figure 3. Neck strength by sex and age in the neutral posture. A) Extension strength. B) Flexion strength. C) Left lateral flexion strength. D) Right lateral flexion strength.](image)

RESULTS
Repeatability
The ICC for the repeated measurements in 34 subjects was
0.66, which can be characterized as “substantial” reliability
(10). The initial measurement for each of these subjects was
used in the following results.

Effects of Sex and Age
Neck strength varied significantly according to participants’
sex, age, and posture ($p < 0.05$; Table 2). The average female
neck strength was nearly half of the average male neck
strength. Combining collegiate and high school athletes
and averaging over all postures, female neck strength varied
from 61% of male neck strength for extension, 54% of male

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neck strength for flexion, and 56% of male neck strength for lateral flexion. For all postures and both sexes combined, the high school athletes’ neck strength ranged from 75% of collegiate athletes’ neck strength for extension, 68% of collegiate neck strength for flexion, and 65% of collegiate neck strength for lateral flexion.

In addition, there were significant interaction effects between sex and age. Specifically, male collegiate athletes were significantly stronger than the other 3 groups (female collegiate athletes, male and female high school athletes), for all postures and force directions (Table 2 and Figure 3). Sex differences in neck strength were greater in the collegiate athletes. Overall postures and force directions, the neck strengths of female collegiate athletes were 44–57% of male collegiate athletes, whereas female high school athletes had 68–79% of the strength of male high school athletes. Age differences (i.e., between collegiate and high school athletes) were only significant in men. The neck strengths of male high school athletes were 54–72% of those of male collegiate athletes, whereas female high school athletes had 78–101% strength of the female collegiate athletes. The largest differences in neck strength were found between female high school and male collegiate athletes, where female high school students had 39–52% of the strength of male collegiate athletes. When strength data were broken down by age in years, significant differences were found consistently for 18- to 21-year-olds but not for 14- to 17-year-olds (Table 3; 0.002 < p < 0.05 for 18- to 21-year-olds; there were not enough subjects aged 22–23 years to compare statistically).

When neck strength was normalized by body weight, there was a significant effect of sex over all directions (Figure 4; 0.001 < p < 0.02). There were no significant age effects, but there were interaction effects of age and sex for flexion,
Effects of Posture

Participants’ neck strength was symmetric with respect to left and right sides. Flexion and extension strengths were symmetric with respect to right or left rotated postures, and right and left lateral flexion strengths were symmetric in the comparable postures (i.e., left lateral flexion in the left rotated vs. right lateral flexion in right rotated; \( p > 0.05 \)). Significant effects of posture were found from repeated measures analysis. However, multiple pairwise comparisons only found differences for extension strength between neutral and 45° rotated postures. On average, extension strength was greatest in the neutral posture (Table 2). Extension strength decreased by 9% (±14%) when the head was rotated 25°, but this decrease was not significant \( (p > 0.05) \). When the head was rotated 45°, extension strength decreased by 18% (±16%), and this difference was significant \( (p < 0.05) \). Flexion strength did not change significantly with posture (Table 2; \( p > 0.05 \)). Lateral flexion strength increased when the head was rotated to the ipsilateral direction (Table 2), but the increase was not significant \( (p > 0.05) \). In 25° ipsilaterally rotated postures, lateral flexion strength increased by 4% (±23%), and in 45° ipsilaterally rotated postures, lateral flexion strength increased by 13% (±32%).

Comparisons Among Force Directions

On average, neck strength was the greatest for extension compared with the other force directions. It should be noted, however, that in some subjects, strength was greatest for flexion or lateral flexion. The ratios of flexion or lateral flexion neck strength to extension strength were largest for male collegiate athletes compared with female collegiate athletes or male or female high school athletes (Table 4). In the neutral posture, the ratio of flexion strength to extension strength was 0.81 (±0.28) for male college students, 0.64 (±0.22) for female college students, 0.71 (±0.27) for male high school students, and 0.71 (±0.24) for female high school students. In the neutral posture, the ratio of lateral flexion strength (in either direction) to extension strength was 0.75 (±0.20) for male college students 0.69 (±0.23) for female college students, 0.61 (±0.21) for male high school students, and 0.59 (±0.20) for female high school students. These trends were similar in other postures, with male college students’ flexion and lateral flexion neck strengths being relatively stronger (closer to their extension strength), compared with female college or high school students.

**Discussion**

The purpose of this study was to examine the isometric neck strength of collegiate and high school athletes. There are

<table>
<thead>
<tr>
<th>Table 4. Flexion and lateral flexion neck strength normalized to extension strength in that posture.*</th>
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<tbody>
<tr>
<td><strong>Male college</strong></td>
</tr>
<tr>
<td><strong>Neutral</strong></td>
</tr>
<tr>
<td>0.81 (±0.28) [0.18–1.49]</td>
</tr>
<tr>
<td><strong>Right rotated 25°</strong></td>
</tr>
<tr>
<td>0.78 (±0.24) [0.27–1.68]</td>
</tr>
<tr>
<td><strong>Right rotated 45°</strong></td>
</tr>
<tr>
<td>0.74 (±0.22) [0.30–1.14]</td>
</tr>
<tr>
<td><strong>Left rotated 25°</strong></td>
</tr>
<tr>
<td>0.84 (±0.23) [0.30–1.44]</td>
</tr>
<tr>
<td><strong>Left rotated 45°</strong></td>
</tr>
<tr>
<td>0.76 (±0.25) [0.32–1.33]</td>
</tr>
</tbody>
</table>

*Data presented are mean (± SD) and range [minimum–maximum].
very few studies that have examined neck strength in relationship to athletic participation, so these data provide important baseline information for future studies evaluating injury risk or training protocols. In this study, neck strength was tested over different force directions (flexion, extension, and lateral flexion) and head postures (neutral and rotated), which provides a more comprehensive profile of neck strength than do many previous studies that measured strength only in the neutral posture, and generally only for extension and flexion. We used a device that is especially designed to measure the neck strength, which restrained the torso and allowed control of head position.

The data support the first hypothesis that male athletes have significantly greater neck strength than female athletes do. Significant sex differences were found in neck strength in both collegiate and high school populations. Female collegiate athletes’ neck strength in this study was 44–57% of male collegiate athletes’ neck strength. In addition, when normalized by body weight, female collegiate athletes demonstrated the lowest relative strength.

These results are consistent with many studies of neck strength in the adult population, which found that female neck strength ranged from 40 to 70% of male neck strength (17,30,31). Two studies found female neck strength to be approximately 70% of male for flexion and 80% of male for extension, but the smaller sex differences in these studies were attributed to either a training effect (14), or size effects because subjects were height matched (29). We found that female high school athlete neck strength was 68–79% of male high school athlete neck strength. These results are higher than those of Lavallee (also previously published as Vincent), who found that female neck strength was 54–64% of male neck strength in children aged 12–17 years (31). The study by Vincent found greater sex differences in the 18- to 23-age group (female neck strength was 42–53% of male neck strength). Vincent also found no significant sex differences in neck strength in children aged 6–11 years, suggesting that sex differences begin to develop in the age range 12–17 years. The high school athletes in this study were of ages ranging from 14 to 17, and consistent with the results of Vincent, sex differences were less pronounced in the results of Vincent.

The data also support the second hypothesis that collegiate athletes have greater neck strength than high school athletes do, but only for men. Male collegiate athletes had significantly greater neck strength than male high school athletes did, but this was not the case for female athletes. The most likely reason for the difference in men is the athletic population: most of the male collegiate athletes were football players, whereas the male high school students participated in football, soccer, basketball, and wrestling. In this study, we considered the school affiliation (high school or college) to be a surrogate for age. There was no overlap in the age of male high school and collegiate athletes. Although the average female group ages were statistically different, there were 17-year-old girls in both the collegiate and high school groups (2 collegiate and 7 high school girls; Table 1).

Studies across professional, collegiate, and high school sport have demonstrated that incidence rates of concussions are similar, but the magnitude of impact and number of impacts increases as the level of play increases (12). One possible explanation for the similar concussion rates between the collegiate and high school level is the less developed musculoskeletal system and diminished ability to control head acceleration after impact (3). Our finding of lower neck strength in male high school athletes compared with that of male collegiate athletes corroborates this explanation.

Neck strength in the athletic population measured here is within the range of other measures of neck strength in the general population. However, there is a large variation in neck strength in other published studies, primarily because of differences in methods. Our results can be most directly compared with those of other studies that used an MCU device (5–8,28). Neck strength of collegiate athletes measured in our study is greater than that in most published adult neck strength research using an MCU device (5–7), which measured average neck strength in the range of 63–115 N in men and 46–74 N in women. Only 1 study using an MCU device had slightly higher neck strength values (124–183 N); this was in a military population of 10 men (28). However, our male and female collegiate neck strength is lower than the adult neck strength in several other studies (11,25,29), which used different methods and measured strength in the range of 197–292 N for men and 74–219 N for women. High school athletes’ neck strength in our study was comparable with the neck strength reported by Vincent (31) for ages 12–17 (59–131 N for men and 44–93 N for women). However, our collegiate athletes’ neck strength was also comparable to Vincent’s data for ages 18–23 years for extension strength (167 N for men and 81 N for women), but the flexion and lateral flexion strength was lower in Vincent’s study (71–90 N for men and 38 N for women).

Few studies have directly compared the neck strength in athletes to that of a control population. Among cyclists, experienced and recreational cyclists did not have greater neck strength than that of control subjects (13). However, elite wrestlers had a greater neck strength than a control group did, although they were not significantly stronger than junior wrestlers (32). The collegiate athletic population in our study appears to be stronger than a general adult population when compared with others using the same device, especially in flexion and lateral flexion. However, it appears that in general, high school athletes are not stronger than other high school students are.

The data only partially supported the third hypothesis that the neck strength varies significantly with posture. The subjects showed large variation in neck strength with posture, but in general, there were no consistent trends among the subjects. With the head in the rotated postures, some subjects had large increases in neck strength, whereas others had large decreases (differences were up to 50%,
either increasing or decreasing). The only significant difference in neck strength with posture was for extension strength, which decreased significantly (18 ± 10%) when the head was rotated 45°. However, even in the 45° rotated posture, extension strength increased by up to 40% for some subjects. The fact that there were not generally significant differences in neck strength with postures (on average) suggests that those whose neck strength was considerably lower in rotated postures may consider training to increase strength in rotated postures. Maintaining constant neck strength throughout different postures may be important, because injuries can occur when the head is not in a neutral posture.

The relative neck strength in different directions may also be an important consideration. The average ratios of flexion to extension strength (0.72 ± 0.26) and lateral flexion to extension strength (0.67 ± 0.22) in our athletic population are on the high end of those found in other studies, which ranged from 0.4 to 0.7 (2,9,14,19,22,30). Further, male college students have the greatest ratios of flexion to extension strength and lateral flexion to extension strength among our subjects, and this may be an effect of training. It should be advantageous to have high neck strength in flexion and lateral flexion, and extension, because head impacts occur in a variety of different directions (3,4).

The role of neck strength in injuries such as concussion is unclear. It is speculated that increasing neck strength may reduce the risk of concussion. Justification for strengthening neck musculature centers on the idea that if the muscles are contracted at the time of impact, the effective mass to be decelerated will be that of the head, neck, and torso, which may decrease the resulting postimpact head acceleration (3). Therefore, tensing neck muscles in an effort to increase effective mass and lessen head acceleration after impact may be an important concussion prevention strategy (1,3,23). Insufficient muscle strength could predispose athletes to concussion because they may not be able to create the muscle force necessary to counter the impact forces that result in head acceleration (16). However, in a study of youth hockey players, higher neck muscle strength alone did not reduce the severity of head impacts (21). The role of neck strength in reducing injury will also depend on anticipation of the impact and the dynamic stabilization properties of neck muscles, which were not studied here. However, future studies exploring the contribution of cervical muscle strength on reducing head impact severity appears to be a logical progression.

Some limitations of this study were associated with the use of the Melbourne Protocol (15) for examining isometric neck strength. This protocol was developed for rehabilitation of cervical spine disorders and meant to capture strength in a functional range of daily activities. We followed the protocol for the order in which strength measurements are taken and the particular postures and strength directions we examined. For example, the Melbourne Protocol was designed such that lateral flexion was only tested to the same side as rotation. Another limitation of the Melbourne Protocol is the lack of randomization between isometric measurements. The same order for strength measurements was followed for each subject. Therefore, differences found between force directions and postures (e.g., lateral bending vs. extension) may be affected by the lack of randomization. However, the differences are more likely to be consistent among subjects because each subject followed the same protocol. Further, we assume that for each subject, the relative change in muscle length with posture is similar. There is also the possibility that fatigue may have affected measurements, particularly lateral bending which was at the end of the experiment. There were rest periods built into the protocol to minimize fatigue. Further, in another study of neck strength in our laboratory (27), we examined strength in the neutral posture at the beginning and end of a sequence of 48 trials (the same number as in this study). On average, the strength at the end of the experiment data was 15% greater than at the beginning of the experiment, although 2 of 10 subjects had force decreases >15%. Therefore, we do not believe that fatigue was a significant factor in this study. Finally, effort and motivation are known to affect maximal muscle activity and the researcher verbally encouraged maximal effort, but this could also be a limitation if effort varied over different postures or force directions.

Practical Applications

There has been little research that has examined neck strength in relationship to athletic participation. The risk of injury in collision sports has recently gained attention in popular literature, the media, and the scientific community. Some researchers have speculated that the strength of the cervical muscles may play a role in the incidence of concussion. This is based on the underlying concept that stronger neck muscles, and thus increased neck stiffness, will result in lower head accelerations during impacts. Normative data on neck strength of healthy athletes could be important to establish reference values for comparative evaluation, especially in the athletic population, as the questions of neck strength and incidence of concussion continue to grow. Having normative data and baseline measurements would be useful for strength coaches, therapists and athletic trainers who work with athletes and often recommend strengthening exercises to relieve pain symptoms. The results of this study provide important information for developing and evaluating training protocols.

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