Occlusion Training Increases Strength and Hypertrophy in Collegiate Male Collision Sport Athletes

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CLINICAL SCENARIO

In collision sports such as football and rugby, muscle strength and hypertrophy are essential for player safety. Historically, strength and hypertrophic gains have been achieved with resistance training. Vascular occlusion or blood flow restriction (BFR) with resistance training has been hypothesized to augment increases in strength and hypertrophy.[1,2,3,4,5] It has even been suggested that the use of BFR and resistance training will allow for strength and hypertrophy gains with greatly reduced initial resistances.[1,2,3,4,5] If this is accurate, BFR and resistance training could allow for rapid strength and hypertrophic gains in a weakened state, such as during rehabilitation from an injury.

PURPOSE

To determine the effect of BFR exercises to increase strength and hypertrophy in collegiate male collision sport athletes compared to unrestricted exercises.

METHODS

Search Strategy
Terms Used to Guide Research
Patient/Client Group: College AND Athlete
Intervention: Vascular Occlusion OR Blood Flow Restricted Training
Comparison: No Intervention AND Control
Outcomes: Increased Muscle Strength AND Hypertrophy
(College AND Athlete) AND (Vascular Occlusion OR Blood Flow Restricted Training) AND (No Intervention AND Control) AND (Increased Muscle Strength OR Hypertrophy)

Sources of Evidence searched
- PubMed
- PEDro Database
- CINAHL
- Sport Discus
- Additional resources obtained via review of references lists and hand search

Inclusion and Exclusion Criteria
Inclusion
- Male only
- Collision Sport
- Level 3 evidence or higher
- Limited to the last 12 years (2002-2014)
- Limited to the English language
- Limited to humans

Exclusion
- Non-contact sports
- Female sample

RESULTS

Five relevant studies were located with our PICO search. Four studies met our inclusion and categorized as shown in Table 1. One additional study investigating occlusion training and serum chemistry was located but not included in this Critically Appraised Topic (CAT) because it did not measure muscle strength or hypertrophic changes.

DISCUSSION AND CONCLUSIONS

Four studies met our inclusion criteria and were reviewed for this CAT. All four investigations demonstrated that a significant increase in muscle strength or hypertrophy occurred with BFR and training. These findings indicate in general, BFR is an effective augmentation to traditional resistance training regimens once risk of thrombosis has been fully explored and minimized.[1,3,4,5]

These results were achieved with the implementation of cuffs or wraps that prevented venous return in the limb. It is suggested that only 50-100 mmHg of pressure is needed to prevent venous return.[5] In a clinical setting, sphygmomanometer cuffs may be utilized to assure proper pressure is applied. Common lifting wraps or commercial BFR straps can be used for a more practical application in the weight room.[3]

Based upon these findings, clinicians could select BFR as an adjunct to a healthy athlete's resistance training plan. In addition, BFR augmentation was shown to be beneficial even when using only a limited amount of resistance.[2,3,4] Benefits were seen with as little as 20-50% of the athlete's single repetition maximal limit (1RM) for a specific activity.[3,4,5] These findings may indicate that an individual can utilize BFR even when they are unable to train at their normal intensity due to injury or fatigue.

Three studies showed an increase in bench press and squat 1RM.[1,3,5] In one of these studies only the lower limbs were occluded during training and bench press still showed a significant increase after the training.[1] This suggests that there may be a systemic effect of BFR as well.[1] In fact, Fujita et al noted an increase in blood lactate, cortisol, and growth hormone following BFR training.[2] This activation appears to be responsible for an eventual increase in muscle protein synthesis.[2]

Future research should investigate effects occlusion / BFR may have on the healing rate of specific tissue injuries such as sprains, strains and fractures. Occlusion training may impact how the metabolites collect in ligamentous, muscular or skeletal tissues. The BFR could lead to greater nourishment being released to the area following occlusion.

In addition, the optimal pressure range of the occlusion during training remains unclear from the literature. The clinician would benefit from research to determine this range. Finally, this CAT should be reviewed in two years to determine whether additional best evidence has been published that may change the analysis for this specific clinical question.

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Table 1 - Characteristics of Included Studies

	Cook et al (2014) Case Control	Luebbers et al (2014) Cohort	Takarada et al (2002) Cohort	Yamanaka et al (2012) Cohort
Participants	Twenty, male semiprofessional rugby union athletes (Age: 21.5±1.4 years, Height: 1.84±0.05 m, Mass: 95.6±10.4 kg) participated.	Sixty-two, male collegiate American football players (Age: 20.3±1.1 years, Mass: 99.1± 19.7kg, and 7.1±2.2 years of weight training experience) participated.	A group of 17 young male rugby players participated (Trained group: Age: 25.9± 0.6 years, n=12. Untrained control: Age: 25.4 ±0.8 years, n=5).	The subjects were 32 NCAA Division IA football athletes (Age: 19.2±1.8 years).
Intervention	Performed 3 exercises (leg squat, bench press, and weighted pull up) at 70% of their 1-RM. 5 sets of 5 repetitions. Lower limb blood flow was restricted with an occlusion cuff inflated to 180 mmHg worn bilaterally at most proximal portion of the thigh during all exercises. It was only inflated during the exercise and deflated during the rest periods.	Four groups completed a 4 time per week, 7-week traditional upper- and lower-body split strength program. Group 1: high-intensity training and supplemental training both with BFR. Group 2: high-intensity training and supplemental training without BFR for either. Group 3: High-intensity training only with no BFR. Group 4: Modified training, supplemental training, both with BFR. The supplemental training consisted of bench press and squat activities using only 20% 1RM.	50% of 1RM exercise combined with an occlusion pressure of about 200 mmHg, low intensity exercise without the occlusion, and no exercise training (untrained control) were included. Bilateral knee extension was performed in a seated position using an isotonic leg extension machine.	The athletes performed 4 sets of bench press and squat in the following manner with or without occlusion: 30 repetitions of 20% predetermined 1RM, followed by 3 sets of 20 repetitions at 20% 1RM of the same exercises. Each set was separated by 45 second rest periods. The training duration was 3 times per week for 4 weeks, after the completion of regular off-season strength training.
Outcome Measures	Primary outcomes: Pre and post test for 1RM bench press, 1RM leg squat, maximal sprint time, countermovement jump power, salivary hormone concentrations Secondary outcomes: Subject compliance	Primary outcomes: Pre and post test for 1RM bench press, 1RM leg squat, and girth measurements Secondary outcomes: Subject compliance	Primary outcomes: Pre and post test measurements of muscle strength and endurance of knee extensor muscles Secondary outcomes: Subject compliance	Primary outcomes: Pre and post test for 1RM bench press, 1RM leg squat, and upper/lower body girth measurements and body mass Secondary outcomes: Subject compliance
Main Findings	Over the 8-week preseason period, mean improvements were observed in bench press (8.6±5.8 kg) and leg squat (12.0±6.7 kg). When the two training interventions were compared, occlusion resulted in significantly greater improvements in bench press (*P*= .004; 1.4%±0.8%), squat (*P*< .001: 2.0%±0.6%), maximal-sprint time (*P*= .016; 0.4%±0.3%), and countermovement-jump power (*P*< .001; 1.8%±0.7%).	Follow up univariate ANOVA indicated a significant difference for 1RM squat in the group that completed high-intensity training and supplemental training with BFR. 1RM Bench press, arm and thigh circumference also increased but were not significant when detected by the ANOVA.	The occluded group showed a significantly larger increase in isokinetic knee extension torque than that in the other two groups (*P*< 0.05) at all the velocities studied. The cross-sectional area of knee extensors increased significantly as well, suggesting that the increase in knee extension strength was mainly caused by muscle hypertrophy. The dynamic endurance of knee extensors estimated from the decreases in mechanical work production and peak force was also improved.	The increases in bench press and squat 1RM (7.0 and 8.0%, respectively), upper and lower chest girths (3% and 3%, respectively), and left upper arm girth were significantly greater in the experimental group.
Level of Evidence / Validity	Level 3b. Validity: N/A	Level 2b. Validity: N/A	Level 2b. Validity: N/A	Level 2b. Validity: N/A
Conclusion	Bilateral lower-limb BFR training with a moderate load produced significant benefits compared with non-occluded training and thus can be considered an effective training stimulus capable of eliciting functional improvements in well-trained athletes.	This study demonstrated that the use of a practical BFR program in conjunction with a traditional high-intensity off-season training program was effective in increasing 1RM squat performance in well-trained collegiate athletes.	Low-intensity resistance exercise combined with vascular occlusion caused, in almost fully trained athletes, increases in muscle size, strength and endurance. Neural, hormonal and metabolic factors would have been involved in the combined effects.	Occlusion training could provide additional benefits to traditional strength training to improve muscular hypertrophy and muscular strength in collegiate athletes.

THE EFFECT OF NECK STRENGTHENING PROGRAMS ON HEAD IMPACT BIOMECHANICS IN COLLISION SPORT ATHLETES: A CRITICALLY APPRAISED TOPIC

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CLINICAL SCENARIO

Concussions are a common sports injury that have short- and long-term effects. Concussions are defined as injuries to the head resulting from blunt trauma, acceleration forces or deceleration forces with some observed signs of other neurological or neuropsychological dysfunction.[1] It has been estimated that between 2.5 milion[1] and 3.8 million[2] concussions occur in the U.S. each year. Once a concussion has occurred, the individual is at an increased risk for extended duration effects[4] and risk for other injuries, including additional concussions.[3,4]

Despite the substantial amount of available literature on concussions, there remains little consensus as to treatment plans once a concussion has occurred. The preferred strategy for clinicians then, should be one to prevent rather than treat concussions. To prevent any injury though, one first needs to know the cause.[5]

One option explored in clinical practice is to alter strength of the head-neck segments. To improve strength at the head and neck could potentially affect segment stability, reducing head-impact biomechanics and therefore concussion incidence risk. Therefore, the purpose of this study is to determine the effectiveness of neck strengthening programs to reduce head impact biomechanics in collision sport athletes.

PURPOSE

The purpose of this Critically Appraised Topic (CAT) is to determine if the literature supports our hypothesis that an increase in neck strength will lessen head impact biomechanics compared to those not enrolled in a neck strengthening program.

METHODS

Search Strategy:
Terms Used to Guide Search
Patient/Client Group: Collision Sport Athletes
Intervention(or Assessment): Neck Strengthening Programs
Comparison: No intervention and control
Outcome(s): Head impact biomechanics
((neck strength OR neck strengthening OR neck muscles OR cervical strength OR cervical strengthening OR cervical muscles) OR (neck AND (resistance training OR muscle strength))) AND (concussion OR brain injuries OR traumatic brain injury)

Sources of Evidence Searched
PubMED @ Duquesne
The Cochrane Library
PEDro Database
Proquest
Sport Discus
Additional resources obtained via review of reference lists and hand search

Inclusion and Exclusion Criteria
Inclusion
Limited to English
Limited to humans
Limited to within the past 10 years (2004-2014)
Level evidence of 2 or higher

Exclusion
Non-collision sport athletes

RESULTS

Three relevant studies[6,7,8] were located and categorized as shown in Table 1. One additional investigation was excluded because it offered Level 4 evidence. Another investigation was excluded as it examined neck segment circumference in relation to incidence of concussion and did not examine joint movement due to perturbation.

In addition to the information in Table 1, two of the selected studies[6,8] had a calculated effect size between .589 and .999. The effect size for the third selected study[7] could not be calculated with the reported data. Instead, the authors reported a 95% confidence interval for linear acceleration ranging from .112 to .987 and rotational acceleration from .060 to .853.

DISCUSSION AND CONCLUSIONS[7]

We designed and composed this CAT to determine if the literature supports our hypothesis that an increase in neck strength will lessen head impact biomechanics compared to those not enrolled in the program. From our research, we determined that there was a limited volume of evidence with no clear consensus to support our hypothesis. As such, we cannot advocate, based upon the existing literature, that strengthening of the head and neck segments provides for improved head-impact biomechanics as a proxy to reduce concussion risk.

None of the three studies[6,7,8] found a correlation between neck strength and decreased head impact biomechanics. Each article reported that greater cervical strength limited acceleration and force of the head-neck segment. It was shown in one study[6] that although some participants improved neck muscle strength and size, they did not experience reduced head impact quantifiers. In fact, they found no difference in kinematic, electromyographic or stiffness of the measured segments following the implemented program.[6] It is even possible that head-neck strength could be detrimental to head-impact biomechanics. Mihalik et al. reported that those individuals with stronger upper trapezius strength actually experienced more severe impacts.[7] Lastly, Schmidt et al. stated that neuromuscular training rather than strength training may be a better option in order to lessen the odds of sustaining a force to the head caused by high impact.[8] They reported that greater stiffness decreased the chances of sustaining a higher impact hit.[8]

It was determined that strength in both male and female flexors increased following an 8-week cervical strengthening program.[6] However, in females there was also an increase in neck girth and isometric strength of their extensors.[6] Mihalik et al. did not find evidence to support their hypothesis that increases in cervical neck strength would decrease head acceleration following impact.[7] However, their study examined only isometric neck strength and not dynamic strength.[7] Schmidt et al.[8] measured the peak resultant linear head acceleration (g) using the Head Impact Technology severity profile (HITsp) which was calculated and recorded from the HIT system. A mild impact was defined as a force ≤66g, a moderate impact was between 66g and 106g and ≥106g was considered severe.[8] They also reported that football players were at equal risk for sustaining what they considered a mild or moderate head impact.[8] In contrast, they did note that linemen who had greater right lateral flexor, left lateral flexor, and overall neck strength were at a 1.75 odds for sustaining a moderate rather than mild linear head impact.[8] They concluded that neck strengthening programs may be implemented to increase neck strength but that this intervention may not lead to the desired outcome of altering head impact biomechanics.

Future research should examine the effect of neck strengthening programs and head impact biomechanics in female collision sport athletes. The current research looks solely at male athletes. Research is also warranted to compare head impact biomechanics to individuals of differing age groups, and from different sports to note changes in these demographics. It would also be beneficial to investigate muscle activation intensity and timing in response to anticipated and unanticipated forces. Finally, this CAT should be reviewed in two years to examine if further research has been conducted that would alter the outcome.

Table 1- Characteristics of Included Studies

Study Design	Mansell et al (2005)[6] Prospective Cohort Study	Mihalik et al (2011)[7] Prospective Cohort Study	Schmidt et al(2014)[8] Cohort Study
Participants	36 National Collegiate Athletic Association (NCAA) soccer players, 17 Males [age= 19.21± 0.918 years, mass = 74.33 ±5.11 kg, and height = 69.87 ±2.75 cm], 19 women [age = 19.16 ±0.898 years, mass = 62.15 ±6.36 kg, and height =64.93 ±2.40 cm], had never participated in cervical resistance training, no history of concussions within last 6 months. If previous injury, had to be cleared to play by physician.	37 youth hockey players. 2 AAA level permitted to check in competition, forwards and defenseman from Bantam team (13 and 14 year olds) and Midget team (15 and 16 year olds), age = 15.0 ± 1.0 years, height = 173.5 ± 6.2 cm, mass = 66.6 ± 9.0 kg, playing experience = 2.9 ± 3.7 years.	49 Football players (34 college, 15 collegiate), Age: High school (16.6±.9), Collegiate (20.5 ±1.4), Height(cm): High School(180.4 6.4), Collegiate (189.4±5.1)Mass(kg): High School(87.2±19.0), Collegiate (109.5±18.4). Neck circumference(cm): High School(38.8±2.8), Collegiate(42.9±2.3). Head circumference (cm): High School(58.4±2.0), Collegiate(59.9±2.3). Head-neck length (cm): High School(25.0±1.9),Collegiate(25.8±1.9). No previous head/neck injuries.
Intervention Investigated	The use of an 8 week isotonic cervical resistance program in order to examine the impact on head impact during force application.	To evaluate the effect of cervical muscle strength on biomechanical measures of head impact.	To see if stronger necks during preseason led to a decrease in receiving higher magnitude head impacts.
Outcome Measure(s)	Strength of neck flexors and extensors, Stiffness of head-neck segment, Upper trapezius and sternocleidomastoid: electromyography (EMG) measurements of peak amplitude, area displacement of head and neck segment, kinematic measurements of angular acceleration.	Linear head acceleration, Rotational Head acceleration, Head impact telemetry severity profile.	Computed odds of sustaining moderate or severe head impacts to the odds of low impact based on high and low performers, torque of neck, neck mobility, head impact, cervical stiffness and isometric
Main Findings	Women had 7% head neck length and 20% head and neck mass compared to men. Women's neck girth increase 3.4% over all on average. Pretest and Posttest head-neck segment acceleration were 40% different, 25% more displacement during the unknown vs known-force application, 18% greater peak muscle activity in the unknown force application condition than in the known. Female RTG: increased by 22.5% in posttest vs pretest. In males, sex did not have an impact of kinematic, EMG or stiffness despite greater girth, head-neck segment length and mass and isometric strength	Each strength measure was significantly different across the tertile groups ($P<0.05$). Significant difference in the HITsp in athletes across 3 tertiles of upper trapezius muscle strength ($F_{2,29}= 3.71; P= 0.037$). Athletes with the strongest upper trapezius muscle strength (14.4; 95% CI,14.0-14.8) experienced higher (i.e., worse) HITsp measures compared with athletes with moderate (14.0; 95% CI, 13.5-14.4) or low (13.6; 95% CI, 13.2-14.0) upper trapezius strength. Upper trapezius muscles with more strength(14.4; 95% CI,14.0-14.8) experienced worse (i.e. higher) compared to those with moderate (14.0, 95% CI 13.5-141.4) or low (13.6;95% CI, 13.2-14.)upper trapezius strength.	Linemen with greater right and left lateral flexion and composite strength are at an increased risk(1.75 times higher at sustaining moderate linear impacts. Players with larger SCM, SSC and composite strength had increased odds of moderate to severe head impact. More cervical stiffness and less angular displacement after impact decreased odds of receiving more head impacts.
Level of Evidence; PEDro Score	2; N/A	1b; N/A	2; N/A
Conclusion	8 week isotonic cervical resistance training did not enhance head-neck segment dynamic stability during force application in collegiate soccer players.	"Hypothesis that players with greater static neck strength would experience lower resultant head accelerations was not supported." Contradicts idea that cervical muscle strength lessens head impact acceleration.	Suggests greater cervical stiffness and angular displacement after receiving a force may reduce off of receiving a concussion. Does not state that stronger and larger neck muscles may lessen head impact severity. First study of this nature, does not suggest that cervical neck strengthening programs be eliminated.

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