Volume 2
Issue 3
March 2019

BARBELL MEDICINE

WITH YOU FROM BENCH TO BEDSIDE

Monthly Research Review

Author Information

Jordan Feigenbaum, MD

@jordan_barbellmedicine

info@barbellmedicine.com

Two Guys Walk into a Bar, But Only One Loses Weight

Do Changes in energy intake and non-exercise physical activity affect exercise-induced weight loss? Midwest Exercise Trial-2 by Herrmann et al 2016.

Key Points:

1. Clinically significant weight loss, i.e. >5% bodyweight, can occur in response to an exercise intervention without explicit calorie restriction.
2. The different in weight loss response to exercise among individuals appears to be due to differences in non-exercise energy expenditure and calorie intake, but not differences in resting metabolic rate or exercise compliance, duration, or intensity.
3. Current exercise guidelines appear to be a viable option for producing the recommended weight loss in overweight/obese individuals.

Introduction

In this month's research review we're looking at the varied metabolic responses of individuals to a standardized exercise protocol over 10 months, but first we'll need to review some nomenclature to make sure we're all on the same page. If you prefer to watch rather than read or if you want additional nuance, check out the YouTube video I did on metabolism last December.

Metabolism is defined as all chemical processes that occur within a living organism in order to maintain life. In humans, the amount of energy generated by the body to power all of the chemical processes for 24 hours is termed the total daily energy expenditure (TDEE) and is represented by the unit “Calories” or kilocalories (kCal) [Hargrove 2007]. TDEE is made up of three components:

1) **Basal Metabolic Rate (BMR)** -refers to the Calories per day required to sustain basic life processes and stay awake. It is measured when a person has been fasting for 12 hours, is lying down, relaxed, shortly after waking, and in a thermoneutral environment, i.e. not hot or cold. BMR accounts for 50-70% of total daily energy expenditure. BMR is often confused with resting metabolic rate (RMR), but they are slightly different with RMR not requiring a 12 hour fast – rather a 2-4 hour fast. Subsequently RMR calculations end up being about 10% higher than BMR and thus, accounts for 60-80% of total daily energy expenditure [Gropper 2013]. About 50-70% of RMR is determined by weight, lean body mass, and age- with the remaining 30-50% of variation stemming from race, genetic traits, medical conditions (including acute illnesses), and environment ([Ravussin 1992, Galgani 2018, Bucholz 2001]).

2) **Thermic Effect of Food (TEF)**- also known as diet-induced thermogenesis or specific effect of food. Basically, this represents the amount of energy (aka calories) the body uses in digesting, absorbing, transporting, metabolizing, and storing energy from food. The most commonly cited value for TEF is ~10% of a person’s calorie intake, so 300 calories for someone eating 3000 calories per day [Gropper 2013]. TEF can be increased by eating more protein and dietary fiber- both of which end up being very satiating and potentially help improve results from dieting by improving compliance [Westerterp-Plantenga 2009]. In sum, the thermic effect of food contributes a small amount to total daily energy expenditure- representing about 10% of the total daily calorie intake. It can be increased slightly by eating more protein, more dietary fiber, or eating more in general- however sustained overfeeding will increase RMR in addition to the thermic effect of food.

3) **Physical Activity (PA)** -all calories burned during physical activity fall under this category, which represents 20-40% of the total daily energy expenditure. At present, the 2018 Physical Activity Guidelines for Adults recommend 150-300 minutes of moderate intensity physical activity per week, yet 30% of the US population does zero and of the remaining 70%, less than half meets this recommendation [Piercy 2018]. The physical activity category includes both exercise energy expenditure (EEEx) and non-exercise physical activity (NEPA). NEPA is also known as non-exercise activity thermogenesis (NEAT), but for the sake of clarity, I’ll use the NEPA acronym throughout the rest of this review. Additionally, it should be noted that NEPA (or NEAT) appear to represent the same entity measured by two different units. In the Midwestern Exercise Trial papers, NEPA is measured in minutes and NEEx is measured in kilocalories. That being said,

this convention isn't universal in the nutrition science field and I wanted to try to be as clear as possible.

Okay, so with that background out of the way, let's take a deeper look into this month's paper!

Purpose

The purpose of this paper was to compare metabolic parameters between those who lost >5% of bodyweight, termed *responders*, to those who lose <5% of their bodyweight in response to a standardized exercise intervention. Specifically, the following metabolic parameters were measured:

- Total Daily Energy Intake
- Total Daily Energy Expendtiture (TDEE)
- Non-Exercise Energy Expenditure (NEEx)
- Resting Metabolic Rate (RMR)
- Non-exercise physical activity (NEPA
- Sedentary Time

There are a number of other papers published from this trial looking at weight regain, excess post exercise oxygen consumption, and many other outcomes. If you're interested head over to PubMed and search for "Midwestern Exercise Trial."
Subjects:

In this study, 141 individuals were stratified into one of three groups:

1) Control (no exercise)
2) 400kCal expended per exercise session
3) 600kCal expended per exercise session

Participants were comprised of 63 men and 78 women, ages 18-30, who were overweight/obese based on BMI, previously sedentary, and who were able to exercise.

Other characteristics of the subjects can be seen in Table 1 below.

****Continued on next page****

Table 1	Female			Male		
	Control (n=15)	400kCal/session (n=31)	600kCal/session (n=32)	Control (n=11)	400kCal/session (n=22)	600kCal/session (n=30)
Age (yrs)	21.7	23.3	22.1	23.2	23.1	22.8
Weight (kg)	78.7	84.5	82.9	98.9	97.9	104.7
BMI (kg/m²)	29.5	29.1	29.5	31.1	31.6	32.9
Fat (%)	44.6	44.4	44.5	37	34.5	37

Table 1: *All values are reported as averages. Of note, look at the BMI and body fat differences between men and women in this trial. It is likely that the men, despite their higher BMI's, were carrying more lean body mass than the women given their body fat levels.*

The subjects also reported being "weight stable" for the 3 months preceding the study, but the authors admit that this included up to a. 4.5kg (9.9lbs!) swing in weight, which isn't really weight stable, but I digress.

Methods

The exercise interventions consisted primarily of walking/jogging on a treadmill 5 times per week, though stationary biking, ellipticals, and/or walking outside was allowed for 1 session per week.

Exercise energy expenditure (EEEx) per session gradually increased from 150kCal per session to 400 or 600kCal per session. The duration of exercise required to burn 400 or 600 kCal/session was determined by measuring each individuals VO2 while the participants were walking or jogging on an inclined treadmill at 70-80% of their max heart rate. EEEx levels were selected based on recommendations from The American College of Sports Medicine Position Stand "Appropriate Physical Activity Intervention Strategies for Weight Loss and Prevention of Weight Regain for Adults."[Donnelly 2009]

All exercise was supervised by members of the research team with exercise duration verified by heart rate monitors. Compliance was defined as completing >90% of the scheduled exercise sessions and those who were non-compliant during any of the 3 month intervals (0-3, 3-6, 6-9) were dismissed. **74 of the 115 participants** in the exercise groups (64%) complied with the intervention.

Participants in the control group did not participate in the exercise intervention.

Bodyweight data was measured between 7am and 10am following a 12 hour fast while wearing a hospital gown, for what that's worth. Body fat levels were assessed using DEXA scans.

Energy and macronutrient intake data were assessed over 1-week periods of ad libitum eating in a monitored cafeteria at University of Kansas (where the research was performed). The researchers used a pretty ingenious way of making the dietary recall more accurate and more useful. Their description is as follows:

"Two digital photographs (90° and 45° angle) were obtained before and after consumption of each meal with the cafeteria trays placed in docking station to standardize the camera angle. Notes were placed on the tray to identify beverages (e.g., diet vs. regular soft-drink; skim vs. whole milk, etc.) and other food items that would be difficult to identify from the photo. Foods consumed outside the cafeteria (e.g., snacks, non-cafeteria meals) were assessed using multiple-pass recalls."

Interestingly, the baseline data from this study suggests that the digital photography provided estimates of energy intake over 7 days within ~6% of TDEE assessed by doubly labelled water (DLW), which they also performed on individuals in this story in order to determine their TDEE. Briefly, the doubly labeled water (DLW) contains a "label" or tracer that is absorbed into the human body and later, eliminated from the body in the urine. Participants drink the special water and then, over the next 7-14 days, collect their urine for analysis by researchers. Knowing the rate of tracers ingested and eliminated, the total metabolic rate may be estimated from existing equations and this is currently the gold standard for determining TDEE in free-living (outside the lab) conditions.

Finally, non-exercise physical activity (NEPA) and sedentary time was assessed by a knock-off waist-mounted FitBit that was worn for 7 consecutive days (10 hours per day) at the various time intervals where NEPA and sedentary time were assessed by the researchers. Sedentary time was defined as, "time with accelerometer readings below 100 counts/min," where counts are movements determined by the accelerometer.

Of note, there was only about 6 days of valid data (10 hour wear time) to calculate the NEPA and sedentary time, whereas data from **the same author** suggests a wear time of 12 hours per day may substantially underestimate activity [Hermann 2014].

Findings

As noted above, 64% of the participants in the exercise groups complied with the study by completing 90% or more of the exercise sessions. This means 44% failed to comply, **but there were no significant differences in baseline characteristics** between those who did or did not comply.

In this 10 month trial, weight loss >5% of initial bodyweight, termed *responders* (8.4kg on average), were comprised of 20 men and 20 women, which represented **54% of <u>all</u> exercising participants.** *Non responders*, those losing <5% of initial bodyweight (0.04kg on average), were comprised of 17 men and 17 men or **46% of <u>all</u> exercising participants.**

Interestingly, there were no differences in responders or non-responders based on which exercise intervention, 400kCal or 600kCal per session, they were assigned to. For the rest of the results, both exercise interventions' data are combined.

Fat-free mass (FFM) is all tissue that is not fat, e.g. muscle, bone, water, organ tissue, etc. FFM was basically unchanged across the total sample from baseline until the 10 month end point and there were no meaningful differences between responders and non-responders throughout the study. That said, baseline FFM was higher in the non-responder men (~68kg) compared to the men who responded to the intervention (62.3kg).

Fat mass (FM) decreased significantly in all responders, down an average of 7.8kg and 7.0kg in men and women, respectively. In the non-responders however, fat mass was increased in men by 0.3kg and only decreased in women by 1.2kg on average. That's a 8.1kg and 5.8kg difference in average FM in men and women, respectively.

Waist circumference decreased in responders by 8cm in men and 5cm in women on average. Non responders also decreased their waist circumferences by 1.3cm and 2.6cm in men and women, respectively.

There were no differences in exercise-induced energy expenditure (EEEx) in responders and non-responders or between sexes and this was measured using the doubly labeled water (DLW) technique described above.

Total daily energy expenditure (TDEE) **increased** in male responders by ~ 310kCal/day and **decreased** in male non-responders by 17kCal/day. TDEE increased in both female responders and non-responders by 344 kCal/day and 335kCal/day, respectively.

Resting metabolic rate (RMR) **decreased** in responders by about 126kCal/day for men and 41 kCal/day for women, whereas it **stayed the same** for non-responders of both sexes.

Non-exercise energy expenditure (NEEx), e.g. the caloric representation of non-exercise physical activity (NEPA) or non-exercise aerobic thermogenesis (NEAT), **increased** in male responders by 142kCal/day and **decreased** in male non-responders by 260kCal/day. This corresponded to an **increase** in NEPA by about 66 minutes in male responders, whereas male non-responders saw a 30 minute/day **drop** in NEPA on average.

Sedentary time per day **decreased** in the male responders by about 27 minutes when comparing baseline to 10 month values. That said, male non-responders saw an **even larger decrease** in sedentary time- meaning they were actually **more active by 12 additional minutes**- than the male responders. This was seen despite their decreased NEEx and NEPA. In short, the non-responder men were less sedentary outside of their prescribed exercise than their responder counterparts, but it didn't burn enough calories to matter.

There were **no significant changes** in NEEx, NEPA, or time spent being sedentary in females regardless if they were responders or non-responders.

Perhaps **most importantly**, there were **higher** energy intakes in non-responders compared to non-responders that were statistically significant at 3.5 months and 7 months, and came close to being significantly different at 10 months (p=0.053 and <0.05 is the cut off for significance).

Over the 10 month period, energy intake **decreased** *slightly* in responders and **increased** *slightly* in non-responders, but neither of these changes were statistically significant for any group at any time.

Why does this article matter?

This article offers good insight into some very important public health-related questions.

How much weight loss is needed in order to produce improvements in health?

The 2016 American Academy of Clinical Endocrinologists (AACE) guidelines for managing patients with obesity recommends weight loss 5-15% of body weight for management of conditions including metabolic syndrome, pre diabetes and Type 2 Diabetes Mellitus, high blood pressure, female infertility, male hypogonadism, obstructive sleep apnea, asthma, and more based on the data suggesting significant improvements in outcomes published in the 1700+ studies reviewed. [Garvey 2016]

Therefore, the cut-off point of 5% between responders and non-responders in this study is useful in determining whether exercise alone can help obese individuals lose a clinically meaningful amount of weight. The answer appears to be that the majority of people can (56% of participants in this trial could), however I would like to point out two things:

1) The study being reviewed did not include resistance training as part of the exercise intervention, despite its recommendation in both the 2018 Physical Activity Guidelines for Adults and 2016 AACE guidelines on obesity.

2) The study also did not explicitly advocate (and counsel) for a calorie-restricted diet, which should be a priority in overweight or obese individuals.

While these two omissions of the study allow us to assess the effects of aerobic exercise alone on body composition and metabolic parameters, it also provides us an opportunity to discuss additional elements of obesity management that improve outcomes. In short, all overweight and obese individuals without other contraindications should be counseled on aerobic exercise and resistance training in order to meet the published physical activity guidelines **AND** should receive further counseling on dietary interventions designed to produce a calorie deficit in order to produce the best clinical outcomes [Garvey 2016, Piercy 2018 .]

Finally, the paper highlights that there are considerable variations in how individuals respond to a given exercise intervention. In this study, we see an 8kg weight loss difference between responders and non-responders that, based on the presented evidence, can only be partially explained by differences in energy intake.

Yes, it is true that the non-responders had statistically higher energy intakes compared to the responders at baseline, 3.5 months, and 7 months. It is also true that in general, non-responders' energy intakes increased over the course of the study, whereas the responders' energy intakes decreased. That said, the energy intake differences just **barely** reached statistical significance at these time points and **did not** reach statistical significance at 10 months' time- the end of the study. To me, this suggests that the absolute difference in calorie intake wasn't very large, rather the variable response to the exercise intervention was due to other factors such as genetics, subclinical disease states altering the hormonal milieu, etc.

This notion is further supported by the data reported here suggesting no difference between the 400kCal/session and 600kCal/session groups. If everyone responded the same to a given amount of exercise, we'd likely see a larger response in weight loss in the 600kCal/session group if given enough data points. We didn't see that in this study, as weight loss outcomes were not different between exercise interventions. This suggests some mechanism or group of mechanisms that attenuated the weight loss in the higher calorie per session group or conversely, increased the weight loss in the lower calorie per session group.

My take on the matter is that there are many biological, psychological and social inputs that influence behavioral change and thus, outcomes. It seems reasonable that the sum of those inputs are likely different amongst individuals and are responsible for the differences in response to a given set of interventions.

When identifying an individual or group of individuals who do not respond well to a given intervention, it is incumbent upon the person (or persons) calling the shots to change the dose or the formulation in order to produce the desired outcome. In this particular case, I'd likely add nutritional counseling and recommend resistance training to the non-responders in order to help achieve the desired weight loss before "increasing the dose" of aerobic exercise.

Alright, that's it from me this month. Hope you enjoyed it. See you next month ☺

References

1. Hargrove, J. L. (2007). Does the history of food energy units suggest a solution to Calorie confusion? *Nutrition Journal*. https://nutritionj.biomedcentral.com/track/pdf/10.1186/1475-2891-6-44
2. Gropper, Sareen S.; Smith, Jack L.. Advanced Nutrition and Human Metabolism Cengage Textbook. 2013.
3. Ravussin E, Bogardus C. A brief overview of human energy metabolism and its relationship to essential obesity. Am J Clin Nutr. 1992; 55:S242S–45. https://www.ncbi.nlm.nih.gov/pubmed/1728837
4. Galgani, J. E., Castro-Sepulveda, M., Pérez-Luco, C., & Fernández-Verdejo, R. (2018). Validity of predictive equations for resting metabolic rate in healthy humans. Clinical Science, 132(16), 1741–1751. doi:10.1042/cs20180317 https://www.ncbi.nlm.nih.gov/pubmed/29967004
5. Buchholz, A. C., Rafii, M., & Pencharz, P. B. (2001). Is resting metabolic rate different between men and women? British Journal of Nutrition, 86(06), 641. doi:10.1079/bjn2001471. https://www.ncbi.nlm.nih.gov/pubmed/11749674
6. Westerterp-Plantenga, M. S., Nieuwenhuizen, A., Tome, D., Soenen, S., & Westerterp, K. R. (2009). Dietary protein, weight loss, and weight maintenance. Annual Review of Nutrition, 29, 21–41 https://www.ncbi.nlm.nih.gov/pubmed/19400750
7. Donnelly JE, Washburn RA, Smith BK, et al. A randomized, controlled, supervised, exercise trial in young overweight men and women: the Midwest Exercise Trial II (MET2). *Contemp Clin Trials*. 2012;33(4):804-10.
8. Garvey, W. Timothy, et al. "American Association Of Clinical Endocrinologists And American College Of Endocrinology Comprehensive Clinical Practice Guidelines For Medical Care Of Patients With Obesity." *Endocrine Practice*, vol. 22, no. 7, 2016, pp. 842–884., doi:10.4158/ep161356.esgl.
9. Piercy KL, Troiano RP, Ballard RM, et al. The Physical Activity Guidelines for Americans. *JAMA.*2018;320(19):2020–2028. doi:10.1001/jama.2018.14854
10. Donnelly JE, Blair SN, Jakicic JM, Manore MM, Rankin JW, Smith BK. American College of Sports Medicine Position Stand. Appropriate physical activity intervention strategies for weight loss and prevention of weight regain for adults. Medicine and Science in Sports Exercise. 2009; 41:459–471.

Author Information

Austin Baraki, MD

@austin_barbellmedicine

draustin@barbellmedicine.com

Perception of schoolbag heaviness matters more than absolute loads among high school students with back pain

Citation: Prevalence of low Back pain among adolescents in relation to the weight of school bags

By Fatemah Akbar et al. 2019

Key Points:

1. The research literature remains unclear on strong risk factors for pediatric and adolescent back pain, but one commonly cited risk factor involves the weight of schoolbags used by children. In fact, multiple professional organizations have recommended -- without strong supporting evidence -- that school bag weight not exceed 10 to 15% of a student's body weight due to these concerns.
2. In this cross-sectional study of 918 students from different high schools in Kuwait, 1) absolute school bag weight, 2) school bag weight relative to body weight, and 3) school bag carrying style appeared to have no association with back pain. Instead, the only factors that showed a clear association with back pain were 1) female sex and 2) students' subjective perception of bag heaviness.
3. While this cross-sectional study cannot demonstrate direct causation between these factors, these findings fit in with much of what we know from the broader research literature on the biopsychosocial contributors to back pain in the adult population, and suggest that absolute external loads should not be used to guide recommendations with respect to back pain.

Introduction

Back pain has an enormous global burden, consistently among the leading causes of years lived with disability among adults.[GBD 2017] It has a similarly high prevalence and burden among children, with a recent multinational study showing that the prevalence of back pain was 27%, 37% and 47% among children aged 11, 13 and 15 years, respectively.[Swain 2014] The research literature remains unclear on strong risk factors for pediatric and adolescent back pain, but one commonly cited risk factor involves the weight of schoolbags used by children. In fact, multiple professional organizations including the American Occupational Therapy Association and American Academy of Pediatrics have recommended that school bag weight not exceed 10 to 15% of a student's body weight due to these concerns.[Dockrell 2013] [Lindstrom-Hazel 2009]

Purpose

This study aimed to estimate the prevalence of low back pain in public high school students in Kuwait, and to investigate the association between LBP and various risk factors, including schoolbag weight.

Methods

The authors performed a cross-sectional study on a total of 950 students from 12 different public high schools in Kuwait. Students were aged between 14 and 19 years, 56.4% male and 43.6% female. Subjects were recruited via cluster random sampling to obtain a representative sample in proportion to the size of their schools.

Data were collected via face-to-face interview with students using a standardized questionnaire. The questionnaire was designed to obtain information regarding the prevalence, intensity, and frequency of back pain, its impact on daily activities and school attendance, treatment obtained, as well as injury and menstrual history.

Students' height, weight, and schoolbag weight were measured. Additional information was obtained regarding students' *perceived heaviness* of their school bags (i.e., "light", "normal", "heavy", "too heavy"), as well as their daily school bag carrying habits. Data from 918 students were ultimately included for final analysis.

Findings

Table 2 shows the reported prevalence of back pain across various time points, as well as the average reported severity: 5.48 on a 1-10 scale. Of note, approximately 70% of students reported a history of back pain lasting a day or longer, with 86% reporting *multiple episodes of this back pain in the past month*.

****Continued on next page****

Table 2 – Prevalence of low back pain amongst 950 public high school students in Kuwait, 2017		
Question	**n**	**(%)**
Have you ever felt low back pain that lasted a day or longer?		
Yes	668	(70.3)
Have you felt low back pain that lasted a day or longer in the last 6 months?		
Yes	466	(49.1)
Have you felt low back pain that lasted a day or longer in the past month?		
Yes	293	(30.8)
How many times did you feel this back pain in the last month? (n=293)		
Once	39	(13.3)
2-3 times	120	(41.0)
4-5 times	57	(19.5)
6 times or more	77	(26.3)
Severity of LBP[a], mean (SD)[b]	5.48	(1.6)

Authors reported *odds ratios* for various associations with a history of back pain within the prior 6 months. **Odds ratios** are a statistical measure of association between an exposure and outcome. They describe the odds of a particular outcome given an exposure of interest, compared to the odds of that outcome occurring *without* the exposure.

When looking at the absolute weight of school bags (i.e., the "exposure"), no significant association was found with back pain (i.e., the "outcome") at any weight range. Specifically: compared to the lightest bags of < 5.32 kg, bags weighing in the range of 5.33-7.35 kg or > 7.36 kg showed no increase in odds of back pain, as shown in the section of table 3 shown below.

Table 3 - Association between low back pain and the weight of school bag and other risk factors among 918 public high school students in Kuwait, 2017		
Factor	**Odds ratio of LBP (6-month)**	
	OR [95% CI]	p-value[1]
Bag weight in kg		
≤ 5.32	1.00 [Reference]	0.620
5.33–7.35	1.17 [0.85–1.61]	
≥ 7.36	1.10 [0.80–1.50]	
Bag weight as percent of body weight		
< 10%	1.00[Reference]	0.041
10 to 15%	1.42 [1.07–1.90]	
≥ 15%	0.95 [0.62–1.10]	
Gender		
Males	1.00 [Reference]	<0.001
Females	2.17 [1.66–2.82]	

There were no significant relationships between reports of back pain and age, nationality, school system, parental level of education, smoking, student GPA, or student BMI. **Of note, females had 2.17 times greater odds [95% CI 1.66-2.82] of back pain compared to males**.

There was a significant relationship between *perceived* heaviness of school bags and back pain. Compared to students who perceived their bags as being “light”, those who perceived them as “heavy” had an odds ratio of **1.98** [95% CI 1.13-3.50], and those who perceived them as “very heavy” had an odds ratio of **4.20** [95% CI 2.19-8.06]. In fact, once adjusted for *perceived* heaviness, **bag weight relative to body weight showed no relationship with back pain.** The lack of relationship between relative or absolute loads and back pain persisted upon repeated multivariate analyses that specifically *excluded* data on perceived heaviness.

Table 3 - Association between low back pain and the weight of school bag and other risk factors among 918 public high school students in Kuwait, 2017

Factor	Odds ratio of LBP (6-month)	
	OR [95% CI]	p-value[1]
Perceived heaviness of school bag[1]		
Light	1.00 [Reference]	< 0.001
Normal	1.24 [0.70–2.18]	
Heavy	1.98 [1.13–3.50]	
Very heavy	4.20 [2.19–8.06]	
Carrying a school bag ≤4 days or never[3]	1.00 [Reference]	< 0.001
Carrying a school bag every day	2.84 [1.72–4.68]	
Number of bags taken to school		
None	1.00 [Reference]	< 0.001
One	2.95 [1.76–4.97]	
Two	4.14 [1.56–11.00]	
More than two	8.00 [.79–81.25]	
The way of carrying school bag[4]		
On two shoulders	1.00 [Reference]	0.384
On one shoulder	1.02 [0.72–1.43]	
Others	0.54 [0.98–1.33]	

Other notable findings included increasing odds of back pain with each additional school bag the student carried to school (none < 1 < 2 < more than 2 bags). There was also **no correlation identified with the carrying technique** (e.g., on one shoulder vs. two vs. others), which has historically been a frequent concern with respect to back pain.

The authors state: ***“Throughout the analysis, the only factors that remained consistently associated with LBP were gender and how the students perceived the heaviness of their bag.”***

Discussion

We have previously discussed the repeated failures of a biomedical approach to back pain, and this article demonstrates yet another. Under such a traditional mechanically-focused model, it seems superficially plausible (maybe even *likely*) that individuals carrying higher absolute loads would be more likely to report incident back pain — especially if they were being carried in an "incorrect", asymmetric (e.g., on one shoulder), or otherwise "dangerous" fashion. Purported mechanisms might include the pure mechanical stress, "wear and tear", and potentially asymmetric forces generated by such loads, as is commonly assumed both among the lay public and among healthcare professionals today.

Based on this sort of hypothesis alone, multiple professional organizations including the American Occupational Therapy Association and American Academy of Pediatrics have recommended that school bag weight not exceed 10 to 15% of a student's body weight. As it turns out, we do not have much evidence to support such recommendations; in fact, we have mounting evidence contradicting them — as well as the entire underlying model of pain used to support such recommendations. In fact, a 2018 systematic review of 69 studies (n = 72,627) found no evidence that factors such as schoolbag weight, design, or carriage method increased the risk of back pain in children.[Yamato 2018]

An obvious limitation of this study is the cross-sectional approach — in other words, a study looking at a "snapshot in time". For this reason, the data and analyses presented are merely *correlational* in nature. A more compelling (but also more expensive, complex, and time consuming) study approach would involve prospectively following students forward in a controlled fashion over time, and observing rates of incident back pain compared to baseline ratings of perceived bag heaviness.

For example, based on the current study methodology it remains equally plausible that students who have back pain are more likely to perceive their bags as being heavier (i.e., reverse causation), whether due to the pain or due to some other factor. Similarly, a type of reporting bias may also explain these findings, as it is plausible that students with back pain might report their bags as feeling heavier due to a conscious or subconscious attribution of their pain to the school bag.

Nonetheless, the authors argue (emphasis ours),

> *"Finally, it is possible that the association between LBP and how the students perceive heaviness of their bag is genuine and that LBP may be the result of what a student considers to be a heavy bag.* ***As such, the perceived heaviness of school bag by students may be a better measure of the impact of the exposure than the actual bag weight, which overlooks many individual factors, such as strength of the muscles, mental preparedness to carry the***

bag, and many others. In other words, the student is the best judge to define what a heavy bag is for him/her … Therefore, recommendations on the weight school bag should be based on each student's judgment on the heaviness of their bag."

And when looking out at the broader literature on back pain, this final idea comports with what we know about the significance of psychosocial factors with respect to pain. It is interesting to consider the potential psychosocial influences driving the sex difference observed in this study as well, particularly given the sociocultural context in a Middle-Eastern country like Kuwait. A more biopsychosocial approach recognizes the multitude of factors that can influence the brain's threat assessment and the ultimate drive for protection. Indeed, Dockrell et al. write of one other study on the subject:

> *"... when the children's perceptions of bag weight were compared with the percentage of body weight carried, one third of those carrying more than 15% of body weight did not perceive the backpack as heavy.* ***It was concluded that we cannot rely on children to safely monitor backpack loads based on their perceptions of that load.1 Alternatively, it could be argued that the children are reliable to safely monitor backpack loads, and that for many of them a load of 15% body weight is a safe load."*** [Dockrell 2013]

These observations also comport with the available sports training literature, where metrics of so-called "internal" training load (i.e., the *perceived* stimulus) appear to correlate more closely with training outcomes and injury risk than seemingly more objective "external" metrics.[Saw 2016] [Eckard 2018] In a similar vein to the authors' conclusion that "*the student is the best judge to define what a heavy bag is for him/her*", in the context of sports training the use of subjective metrics such as RPE allow the trainee to define what a heavy load is for him/her, as this information may be more significant than the absolute load and the coaches' opinions on the matter.

References

1. GBD 2017 Disease and Injury Incidence and Prevalence Collaborators. "Global, regional, and national incidence, prevalence, and years lived with disability for 354 diseases and injuries for 195 countries and territories, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017" *Lancet (London, England)* vol. 392,10159 (2018): 1789-1858.
2. Swain et al. An international survey of pain in adolescents BMC Public Health 2014 14:447.

3. Dockrell et al. (2013). *Schoolbag Weight Limit: Can It Be Defined? Journal of School Health, 83(5), 368–377.*
4. Lindstrom-Hazel D. The backpack problem is evident but the solution is less obvious. Work. 2009;32(3):329-38.
5. Yamato et al. Do schoolbags cause back pain in children and adolescents? A systematic review. Br J Sports Med. 2018 Oct;52(19):1241-1245.
6. Saw AE, Main LC, Gastin PB. Monitoring the athlete training response: subjective self-reported measures trump commonly used objective measures: a systematic review *Br J Sports Med* 2016;**50:**281-291.
7. Eckard et al. The Relationship Between Training Load and Injury in Athletes: A Systematic Review. Sports Med. 2018 Aug;48(8):1929-1961.

Author Information

Michael Ray, MS, DC

@michael_barbellmedicine

mike@barbellmedicine.com

BARBELL MEDICINE

Adductor Strengthening Protocol - is this the next Nordic Hamstring Curl?

The Adductor Strengthening Programme prevents groin problems among male football players: a cluster-randomised controlled trial. By Harøy et al 2019.

Key Points:

1. This is the first study examining the effects of an adductor-specific, single-exercise intervention effect on prevalence of groin injuries in athletes implemented during pre-season and competitive season.
2. The study intervention demonstrated a reduction in prevalence and risk of groin problems in male soccer players by 41% based on Intention-to-Treat analysis and 47% based on a Per-Protocol analysis.
3. The protocol utilized in this study can be easily implemented during pre-season and during the competitive season for field sport athletes. Additionally, the time requirements are low, no equipment is required, and dosage of protocol can be manipulated based on symptoms and timing of competitive season.

Introduction

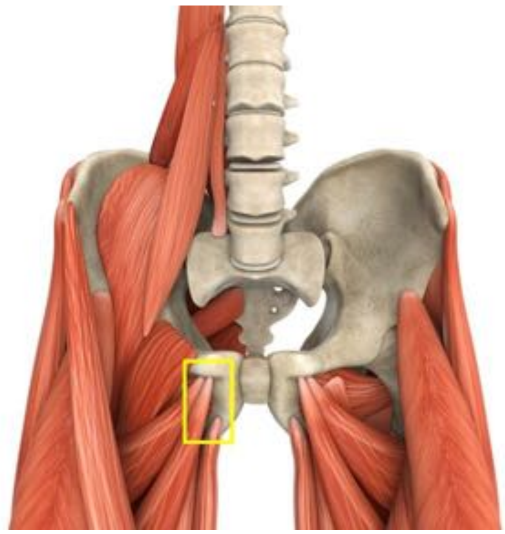
Groin issues are a common problem among soccer (football) players. A 2015 review by Waldén et al found that the rate of groin injury among club-seasonal soccer players was 0.2-2.1 per 1000 hours in men and 0.1-0.6 per 1000 hours in women, with aggregate data indicating a 2.4-times higher rate of groin injuries in male athletes. The authors state:

"The proportion of groin injury during club-season play was 4-19% (aggregated 12.8%) in men's football and 2-11% (aggregated 6.9%) in women's football, suggesting that groin injury comprises a bigger proportion of the total injury burden in male footballers."

To put this rate of groin injury into perspective, if a team has 22 players on their roster with 10 hours of practice/week for 28 weeks (competitive season) that's a total of 6,160 hours. This leads to the statistical probability that between 1-13 males and 1-4 females are dealing with groin issues on a team during a competitive season.

The authors report much of the data was based on a time-loss definition of injury.[Waldén 2015] There is nuance to this based on how "injury" is defined. Such a discussion is beyond the scope of this article; however, it is important to define our terms at the outset.

What is meant by "groin" and "injury"?



According to Doha meeting, 3 categories define clinically relevant structures possibly involved with groin pain:

1. Groin-related structures:
    a. Adductor-related (yellow box)
    b. Iliopsoas-related
    c. Inguinal-related
    d. Pubic-related
2. Hip-related
3. Other[Weir 2015]

Our focus for this article will be adductor-related injury. The adductors are a group of muscles which originate from pubic region and insert into either the femur or tibia. This groups primary action is hip *adduction,* that is, moving the thigh towards midline.

Given the prevalence of groin-related issues in soccer players, and specifically the higher prevalence in males, Harøy et al sought to assess the influence of a specific exercise intervention on reducing groin-related injuries in male soccer athletes during a competitive season. The authors argue that evidence is mixed on the abilities of such interventions to reduce injury rates, and much of this may be related to how an injury is being defined. The authors state:

> *"One limitation of previous groin-specific prevention studies is the use of a time-loss injury definition, an inadequate approach as only about one-third of all groin problems result in time loss. Injuries causing time loss may only represent the 'tip of the iceberg' as a large proportion of players continue to participate despite having groin-related complaints with associated impairments or reduced performance."*

In order to solve this issue, the authors sought a broader definition of injury to include "*all physical complaints*". They utilized the Overuse Injury Questionnaire (OSTRC) to aid with injury surveillance and classification. This approach was implemented according to the authors, "*...in order to capture all cases leading to pain, decreased participation or performance, not only those resulting in time loss.*"

Reported Injury Risk Factors:

Whittaker et al. conducted a systematic review of risk factors associated with groin injuries and found the following variables relevant:

1) Prior groin injury
2) Higher level of play
3) **Reduced hip adductor strength**
4) Lower levels of sport-specific training [Whittaker 2015]

Adductor strength is certainly a modifiable risk factor. A recent video analysis of the biomechanical factors associated with adductor longus strain in football players found (emphasis ours):

> *"Acute adductor longus injuries in football occur in heterogeneous situations. Player actions can be categorised into: change of direction, kicking, reaching and jumping. Change of direction and reaching injuries were categorised as closed chain movements, characterised by hip extension and abduction. Kicking and jumping injuries were categorised as open chain movements, characterised by a change from hip extension to hip flexion and abduction to adduction. Both open and closed chain movements frequently occurred with the hip externally rotated.* ***Despite the variety of situations, a rapid high muscle activation during rapid muscle lengthening may be considered a fundamental injury mechanism for acute adductor longus injuries."***

The authors go on to state (emphasis ours):

> *"Our findings suggest that increasing the capacity of the adductor longus to tolerate rapid loading at a lengthened state is recommended as a key element in injury prevention. Improving the ability of the muscle-tendon unit to tolerate load at a lengthened state may be achieved* ***with eccentric training****."* [Serner 2019]

Now, we aren't fans of the phrase "injury prevention", but perhaps *risk reduction* can be achieved by intervening with eccentric focused adductor exercise(s).

Purpose

Harøy et al conducted a cluster-randomized controlled trial to test the mitigating effects of an adductor-focused exercise protocol on prevalence of groin problems in male soccer players.

Subjects

Data acquisition occurred between February of 2016 to October of 2016. During pre-season (February-March), semi-professional soccer teams in Norway were invited to participate in the authors' study. 35 teams (652 players) initially enrolled in the study but a single team withdrew after randomization. The control group consisted of 242 athletes and the intervention group had 247 athletes, totaling 489 participants.

Methods

The authors created an intervention protocol based on the Copenhagen Adduction exercise (CA) due to prior evidence which demonstrated, "*high activation of the adductor longus muscle, as well as considerable eccentric adduction strength gains following standardised protocols*."

A major benefit of utilizing CA is the lack of required equipment. Furthermore, this particular study utilized regressions of movement for symptomatic players along with a planned manipulation of training variables (i.e., volume and intensity) of the exercise based on whether the athlete was in pre-season or in-season.

For players randomized to the intervention group, the following levels were implemented:

Level 1 - side-lying hip adduction. Figure 1A and B (easiest).
Level 2 - CA but with shorter lever arm. Figure 2A and 2B (moderate).
Level 3 - CA with longer lever arm. Figure 3A and 3B (hardest).

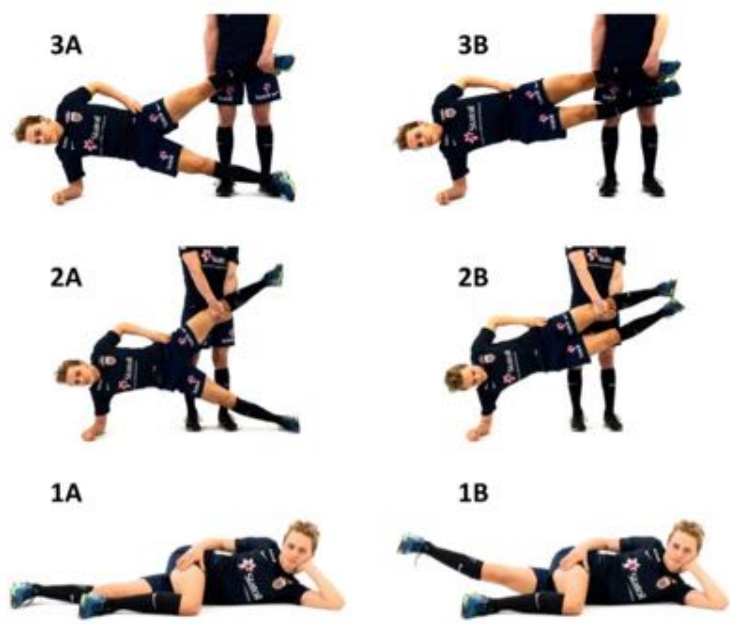


Figure 1 (A) Starting/ending position and (B) mid position for the different levels of the Adductor Strengthening Programme.

[Adductor Exercise - Level 1]

[Adductor Exercise - Level 2]

[Adductor Exercise - Level 3]

[Individual Variation of Adductor Exercise]

Participants were instructed to initially attempt level 3, but if groin pain was experienced during the exercise (>3 on 0-10 pain scale), then regress to level 2. If level 2 presented with similar symptoms, then the athlete regressed to level 1. Regardless of selected level, the exercise was performed bilaterally.

See Table 1 for dosage recommendations of exercise intervention.

Table 1 - Training protocol for the Adductor Strengthening Program

Week	Weekly sessions	Sets per side	Repetitions per side
Preseason (weeks)			
1	2	1	3-5
2	3	1	3-5
3-4	3	1	7-10
5-6	3	1	12-15
7-8	2	1	12-15
In season	1	1	12-15

Outcome measures:

The primary outcome measure was weekly prevalence of ALL groin problems during the athletes' 28-week competitive season. This information was recorded via the previously-mentioned OSTRC tool. The authors also recorded secondary outcome measures consisting of the weekly prevalence of "*substantial*" groin problems during the competitive season, as defined below.

Each week the participants completed the questionnaire via a smartphone application. A notification was sent to each participant to complete the survey on Sunday, followed by a short message service (SMS) notification on Monday. If a participant had not completed the questionnaire by Thursday, they received an additional SMS notification. If a participant still did not complete the questionnaire, then they were contacted by phone for the information. Of note, the authors did input missing data retrospectively. During the last four weeks of the season, the authors visited each team and had participants complete their missing data by recall. Participants were provided with prior questionnaire responses to help with recall.

How were "groin problems" defined?

1. Any hip or groin symptoms reported in the questionnaire.

2. Any symptoms to include:
    - "*pain, ache, stiffness, clicking/catching or other complaints related to the groin"*
    - Reduced training participation, training volume or performance due to groin problems
    - Players categorized with substantial groin problems when reporting "*moderate or severe reductions in training volume or football performance, or a complete inability to participate due to groin problems.*"

The authors then analyzed the data for correlation between the prevalence of *all* groin problems, "substantial" groin problems, and their exercise intervention. Analyses of the data were based on the 28-week timeframe during the competitive season (April - October). If players had a <75% response rate they were excluded from the final dataset (<21 weekly reports).

Primary *Intention to Treat* (ITT) analyses were completed as well as a secondary *Per-Protocol* (PP) analysis. The PP analysis excluded players who completed <67% of the intervention protocol pre-season or <50% during competitive season. Hopefully, having both of these analyses will help mitigate bias and confounding factors affecting the data and interpretation thereof.

****Continued on next page****

Findings

Table 4 – Generalised estimating equation (GEE) model for both intention-to-treat and per-protocol analyses.

	Mean difference in prevalence (%)	OR*	95% CI	P values
All problems				
Intention-to-treat	7.8	0.59	0.40 to 0.86	0.008
Per-protocol	9.6	0.53	0.36 to 0.78	0.001
Substantial problems				
Intention-to treat†	2.3	0.82	0.51 to 1.33	0.42
Per-protocol‡	3.4	0.70	0.40 to 1.23	0.22

*All analyses performed using intervention group as reference value.
†Age, years as senior, height and weight were included as covariates in the GEE model.
‡Height was included as a covariate in the GEE model.

The authors recorded 13,628 weekly reports from athletes. The intervention group averaged a weekly response rate of 74%, while the control group averaged an 80% weekly response rate.

The ITT analyses included 77% of the players who met the required 75% response rate for data inclusion. Of the players included for analysis, both the intervention group and the control group had an average weekly response rate of 90%.

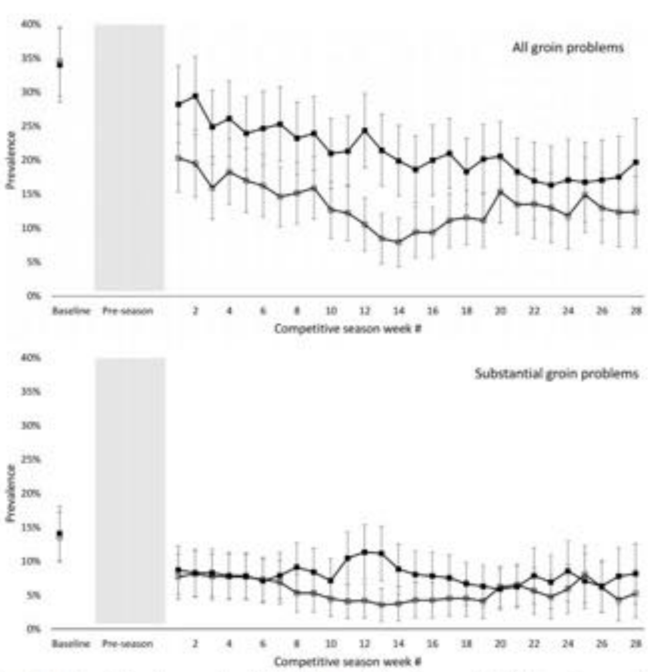


Figure 3 Prevalence of all groin problems (upper panel) and substantial groin problems (lower panel) in the intervention group (open squares) and control group (filled squares) with 95% CI, measured at baseline and 28 times during competitive season for players included in the intention-to-treat analyses. The shaded area represents the period 6–8 weeks the preseason protocol of the Adductor Strengthening Programme was performed.

Primary outcome for Intention-to-Treat Analysis:

During the 28 week competitive season, the intervention group reported an average weekly prevalence of **13.5%** (95% CI 12.3-14.7%) for all groin problems. By comparison, the control group reported an average weekly prevalence of **21.3%** (95% CI 20.0-22.6%) for all groin problems. **The intervention group demonstrated a 41% lower relative risk of reporting groin problems comparatively to the control group.**

Secondary outcomes for Intention-to-Treat Analyses:

The average weekly prevalence of “substantial” groin problems was 5.7% (95% CI 5.1-6.3%) for the intervention group and 8.0% (95% CI 7.5-8.5%) for the control group. This represents an 18% lower relative risk of reporting substantial groin problems compared to the control group, though this finding did not reach statistical significance.

Per-Protocol Analysis:

For the per protocol analysis, the authors found the intervention group demonstrated an average weekly prevalence of groin problems at 11.7% (95% CI 10.9% to 12.5%) and substantial groin problems at 4.5% (95% CI 4.1% to 5.1%).

Table 5 – Characteristics of the groin problems reported during the 28 weeks of the competitive season for players included in the intention-to-treat analysis

	Intervention group (n=844 groin problems)	Control group (n=1321 groin problems)
Time loss (%)	41	33
Graduate onset (%)	78	79
Acute onset (%)	22	21
Dominant leg (%)	45	44
Non-dominant leg (%)	35	34
Both legs (%)	20	22

Major Takeaways:

1. **13,628 questionnaire responses including 2,458 reported groin problems**
2. **ITT analysis demonstrated a cumulative incidence of 55% for all groin problems in the intervention group and 67% in the control group.**
3. **With respect to “substantial” groin problems, 28% incidence in intervention group and 37% in control group.**

Why does this article matter?

This is the first study examining the effect of an adductor-specific, single-exercise intervention on prevalence of groin problems in male football players implemented during pre-season and competitive season.

The primary findings demonstrate a reduction in both prevalence of groin problems as well as risk of reporting problems during a competitive season (41% lower for ITT and 47% lower for PP analyses).

Strengths of this study:

The adductor strengthening protocol utilized in this study can be easily implemented during pre-season and competitive season for the athletes. The time requirements appear low, and no equipment is required beyond having a teammate to help.

The authors also did a great job of manipulating loading of the exercise based on symptoms and timing of competitive season (as demonstrated in Table 1). It's also important to mention the authors did NOT exclude symptomatic players from the intervention. Given prior information discussed at the beginning of this article, we saw many players continue to participate in their sport despite symptoms.

The compliance for this study was overall high comparatively to similar intervention studies. On average, players in the ITT analysis completed 73% of the authors recommended protocol during the preseason and 70% during the competitive season (0.7 times per week with a range of 0.6-0.9). Surprisingly, 42% of players averaged a compliance rate higher than the authors recommendation during in-season. Players included in the PP analysis averaged 93% compliance during pre-season and during the competitive season completed the protocol 0.9 timers per week (range of 0.7-1.0).

Compliance matters A LOT for these situations in order to accurately assess if the intervention has an impact on athletic based injuries. The authors did a great job examining the data via an intention-to-treat and per-protocol analyses to minimize bias from drop-outs and lack of compliance to the interventions in hopes of accurately assessing the impact of their intervention.

Weaknesses of the study:

Single factor examined - The authors study really only examines one potential area with respect to groin pain: the adductor group. Recall at the beginning of this article, Weir et al discussed multiple regions that may be related to the report of groin issues (iliopsoas related, inguinal related, pubic related, hip-related, and other). However, the authors argue that the adductors are the primary area that matters: *"We would argue that targeting the adductors addresses the main problem as adductor-related groin pain accounts for >2/3 of all hip and groin injuries in football."*

No assessment of adductor strength - Another important variable that was lacking from outcome measurements was hip adduction strength pre- and post- intervention. Since we have evidence that eccentric loading of the area is a correlate for groin related injuries, we would like to see if we actually affected strength as a potential explanation for the observed effects of the intervention. According to the authors, we do have evidence for other protocols assessing hip adduction strength (CA - level 3 of this program) showing a 36% increase in eccentric hip adduction strength after an 8 week intensive protocol and an 8% increase in less intensive protocols. This leads into an important unknown: *dosage*. We aren't entirely sure if there is an ideal dosage to mitigate groin issues with such protocols.

Recall bias - The authors retrospectively registered missing data for the last month of the study, which introduces a risk for recall bias.

Deviations from registered protocol - The authors did deviate from their original registered protocol by removing players failing to meet the cutoff response rate standard, which potentially weakens the generalizability of this study to "real-world" situations.

Lack of injury registration methods - There was a lack of reliable methods for registering injuries based on diagnostic information. The authors argue the size of the study didn't allow for "*reliable medical follow-up*". To help with this issue, the authors offered a standard examination to any player experiencing a groin problem affecting match play for two weeks. 26 players took the authors up on their offer and underwent examination The authors state - *"In a future study, the self-reported groin problems should be examined, classified and reported according to the Doha agreement on terminology and definitions."*

Generalizability of findings - this study was on male soccer players. Perhaps we can generalize to other sports like ice hockey and rugby or in female athletes but we need continued research on the topic to demonstrate further efficacy for these populations.

The authors close with this perspective:

> "*The results from the present study suggest that the Adductor Strengthening Programme should be included in football training, among senior male football players. Whether the preventive effect from the Adductor Strengthening Programme can be generalised to female or youth-level football players, as well players at the highest professional level, is not known. Other types of athletes may also benefit from the programme as low hip adduction strength is also considered a risk factor associated with groin problems in other sports with similar movement patterns, such as ice hockey, rugby and Australian rule football.*"

As of right now, based on this evidence, I tend to be in agreement with this stance. Similar to what we see with [Nordic hamstring curls] in the mitigation of hamstring strains, it is likely we should begin prophylactically prescribing an adductor strengthening protocol for athletes in higher risk sports for groin injuries such as soccer. The protocol examined in this study has a low threshold for implementation by not requiring equipment, low time commitment (authors estimate less than 5 minutes), loading can be manipulated based on season requirements, and even progressions are outlined based on symptomatic presentation of the athlete. It would be difficult to find reasons *not* to implement this program. However, there is still nuance to this discussion that will need to be teased out through future study.

References

1. Harøy J, Clarsen B, Wiger EG, et al. The Adductor Strengthening Programme prevents groin problems among male football players: a cluster-randomised controlled trial. British journal of sports medicine. 2019; 53(3):150-157.
2. Waldén M, Hägglund M, Ekstrand J. The epidemiology of groin injury in senior football: a systematic review of prospective studies. British journal of sports medicine. 2015; 49(12):792-7.
3. Weir A, Brukner P, Delahunt E, et al. Doha agreement meeting on terminology and definitions in groin pain in athletes. British journal of sports medicine. 2015; 49(12):768-74.
4. Whittaker JL, Small C, Maffey L, Emery CA. Risk factors for groin injury in sport: an updated systematic review. British journal of sports medicine. 2015; 49(12):803-9.
5. Serner A, Mosler AB, Tol JL, Bahr R, Weir A. Mechanisms of acute adductor longus injuries in male football players: a systematic visual video analysis. British journal of sports medicine. 2019; 53(3):158-164.

WITH YOU FROM

BARBELL

MEDICINE

BENCH TO BEDSIDE

Author Information

Derek Miles, PT, DPT

@derek_barbellmedicine

derek@barbellmedicine.com

Weightlifters Present With Thicker Anterior Cruciate Ligaments (ACLs) Compared to Controls

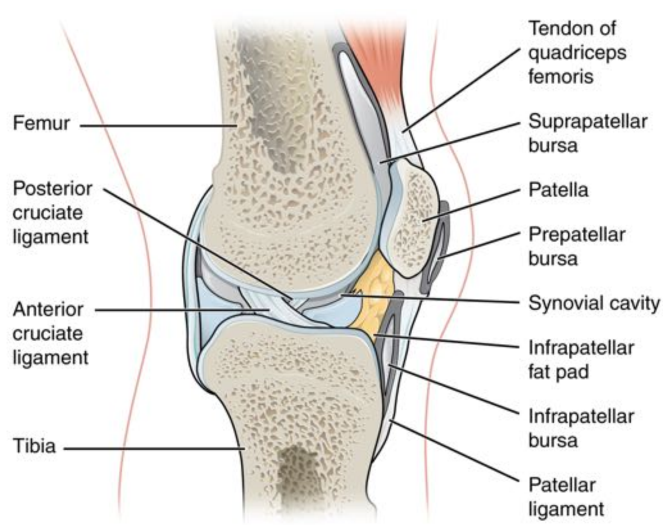
Hypertrophied cruciate ligament in high performance weightlifters observed in magnetic resonance imaging. By Grzelak et al 2012.

Key Points:

1. Individuals with a training history starting at approximately age 10 demonstrated hypertrophied cruciate ligaments compared to age matched controls.
2. Given the current dogma related to youth resistance training being harmful, these result would counter this and lend support to early youth resistance training.
3. The weight training individuals in this study were able to begin training at a young age and demonstrate physiological adaptation to the load that would be considered advantageous.

Introduction

Anterior cruciate ligament (ACL) injuries are an increasingly common injury in the pediatric and adolescent populations. The incidence of ACL injury varies based on sport, and there is a large body of research related to prevention strategies. The adolescent years show a spike in the rate of ACL injury that plateaus beyond 20 years of age.[Renstrom 2008] This span is where many facets of athletic development occur -- and conversely, can be hampered by injury. We have evidence that the incorporation of resistance training can decrease the incidence of injury by as much as one third.[Lauersen 2014] The mechanism by which this occurs is multifactorial, but likely involves physiological changes of tissue structure, tolerance, and function.



Resistance training in youth athletes has fought a dogma for decades that it will stunt the growth of an athlete or cause irreparable damage to their joints. This has since been dispelled in position statements from the American Academy of Pediatrics and an International Consensus Statement from British Journal of Sports Medicine in 2014.[Lloyd 2014, AAP 2008]

Evidence supports that prolonged resistance training can induce hypertrophy of skeletal muscle and bone.[Layne 1999, Ram Hong 2018] Accordingly, ligaments and other musculoskeletal structures should follow.[Schoenfield 2015] Cross sectional area, related to the anterior cruciate ligament, has been shown to increase the tensile strength of the ligament, which should protect against injury.[Lipps 2011] If training modalities can be shown to elicit this effect they likely should be incorporated into training programs early and often. A review from 2012 by Escamilla *et al* showed that exercises such as squats, lunges, and step downs put minimal strain on the ACL which should allow for a gradual exposure to increasing loads.[Escamilla 2012]

Purpose

The purpose of this study was to examine the cross sectional area of the intra-articular knee ligaments in elite level weightlifters versus age-matched controls.

Methods

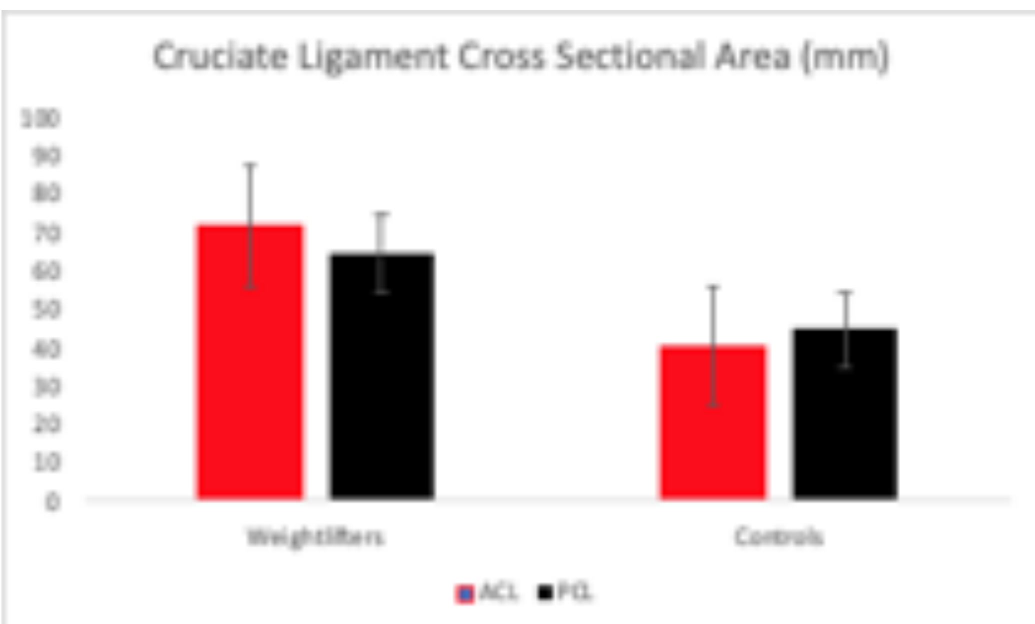
This is a retrospective analysis of a radiology database comparing 9 weightlifters with no history of knee trauma to 19 age-matched controls with no history of knee trauma. For the cohort of weightlifters, 7 athletes had imaging of the bilateral knees. Images were taken on a 1.5T MRI scanner using T1-weighted images with contrast enhancement. Measurement of ACL thickness was taken at half the length of the ligament, determined as the middle distance between femoral and tibial attachments on a sagittal view. Posterior cruciate ligament measurements were carried out in the bottom third of the ligament. Base characteristics of both cohorts can be found in Table 1.

****Continued on next page****

Table 1 - Participant and control group participant data		
Characteristics	Weightlifters (n=9) Mean +/- SD	Controls (n=19) Mean +/- SD
Age (years)	26.1+/-4.2	26.6+/-5.3
Weight (kg)	92.6+/-14.8	86.6 +/-8.8
Height (cm)	177.6 +/-6.4	179.8+/-5.4
BMI (kg/m2)	29.1+/-2.7	26.8+/-2.2
Training Participation (years)	15.5 +/-4.7	N/A
Age at start of training (years)	10.6+/-0.8	N/A

Findings

The authors found that the individuals in the weightlifting cohort possessed hypertrophied ACL and PCL ligaments compared to their peers controls. **On average, weightlifters' ACLs were approximately 78% larger than those of age matched controls.** Weightlifters presented with a mean ACL CSA of 71.7mm^2 (range 52.9-111.2) versus non-lifters mean of 40.56 (range 23.83-59.1). This falls in line with the measurements provided by Iriuchishima *et al* from 2016 which found a mean 46.9 +/-18.3.[Iriuchishima 2016] PCLs in the weight trained cohort averaged 64.48mm^2 (range 52-88.1) compared to 44.98mm^2 (range 31.3-71) in the untrained cohort.



Why This Study Matters

While this study is not without limitations, it is a definitive step towards combating the narrative that weightlifting is inherently "bad for the knees". The increased cross-sectional area of ACLs and PCLs due to ligamentous hypertrophy should add strength to the ligaments, allowing them to subsequently resist higher tensile strain. Certain non-modifiable anatomical features such as medial tibial plateau depth and lateral tibial plateau slopes have shown to be risk factors for sustaining ACL injury.[Khan 2011] Conversely, utilizing weight training to increase the CSA of the cruciate ligaments could represent one way of mitigating that risk.

This study also makes a definitive case that weightlifting can have a positive effect on youth adaptation. The average weightlifter in the study started training at 10.6 years old. This is far below what is commonly seen in today's society, with resistance training rarely being a regular component of training before high school. The last identifiable study analyzing resistance training frequency in the United States did not even discuss a cohort under 18 years old.[Kruger 2006] This same cohort study showed participation in resistance training was much lower among females than males (in the 18-24 age cohort, females were 19.6% and males 36.3%).

As mentioned above, there is an increasing body of evidence that resistance training can have a substantial impact on reducing the risk of injury in athletes, in some studies by as much as one third.[Lauerson 2014] A more recent systematic review by the same authors found that for every 10% increase in strength, there was a 4% reduction in rate of injury.[Lauerson 2018] Females have an ACL tear rate 4 to 6 times higher than their male counterparts in their respective sports.[Hewett 2006] Training programs do exist that have been shown to reduce this risk, but those such as the FIFA 11, which is regularly used, do not contain a resistance training component.[Bizzini 2015] This represents a major gap in the approach to risk reduction in this cohort. Most programs currently utilize neuromuscular training (NMT) paradigms that focus on body weight exercises. In 2015, a meta-analysis was conducted on what would constitute an effective NMT program that came up with three components in order to maximize efficacy [Sugimoto 2015]

- Strengthening
- Proximal Control Exercises
- Multiple Exercise Interventions

A meta-analysis by Steib *et al* explored the most effective dosing of NMT and found 10-15 minutes, two times a week to be most effective.[Steib 2017] This would leave ample time for the development of a well formed, resistance training program with which to further address risk reduction.

I want to be clear, these cohorts were primarily untrained individuals and obviously there would be diminishing returns at some point on strength gains. In the frame of the current review paper, starting athletes resistance training early will allow them to move from the "untrained" to "trained" category at a much earlier age. Theoretically, this should translate into increased cross sectional area of the cruciate ligaments and a protective effect against future injury. The authors of this same study also published a paper on the cartilage thickness of these same individual's knees.[Grzelak 2014] The individuals with a history of weightlifting also had thicker cartilage than their age matched controls. These two findings should be nails in the coffin the resistance training at an early age has detrimental effects on youth development.

This study is not without flaws. It was a retrospective study so a direct correlation that resistance training *caused* ACL hypertrophy is impossible to say. There certainly does appear to be a contributory link. The assessors were not blinded to the cohorts which also could have influenced the measurement of CSA. We also do not know the training history of the individuals in the control group. There likely is heterogeneity in ligament adaptation in sedentary individuals versus individuals who participated in sports without a specific resistance training component. There also is some evidence that peak strength is not a protective factor against non-contact ACL injury.[Steffen 2016] I would argue this study is not a fair assessment as it is easy to hypothesize that stronger and faster athletes likely receive more playing time and would have increased exposure to risk, even if their relative risk was lower. Overall, an ACL tear is a multifactorial event that likely can never be distilled to one protective variable. If, however, size does correlate with increased strength, it would appear that weightlifting can influence that adaptation.

References

1. Bizzini M, Dvorak J FIFA 11+: an effective programme to prevent football injuries in various player groups worldwide—a narrative review *Br J Sports Med* 2015;**49**:577-579.
2. Counsel on Sports Medicine and Fitness. Strength Training By Children and Adolescents. *Pediatrics* 2008; **121**: 835-840.
3. Escamilla RF, Macleod TD, Wilk KE, Paulos L, Andrews JR. Anterior cruciate ligament strain and tensile forces for weight-bearing and non-weight-bearing exercises: a guide to exercise selection. J Orthop Sports Phys Ther. 2012 Mar;**42**(3):208-20.
4. Grzelak P, Domzalski M, Majos A, *et al*. Thickening of the knee joint cartilage in elite weightlifters as a potential adaptation mechanism. *Clin Anat.* 2014 Sep;**27**(6):920-8
5. Hewett T, Ford KR, Myer GD. Anterior cruciate ligament injuries in female athletes: Part 2, a meta-analysis of neuromuscular interventions aimed at injury prevention. *Am J Sports Med*. 2006 Mar;**34**(3):490-8
6. Iriuchishima T, Yorifuji H, Aizawa S, Tajika Y *et al*. Evaluation of ACL mid-substance cross-sectional area for reconstructed autograft selection. Knee Surg Sports Traumatol Arthrosc. 2014 Jan;**22**(1):207-13
7. Khan MS, Seon JK, Song EK. Risk factors for anterior cruciate ligament injury: assessment of tibial plateau anatomic variables on conventional MRI using a new combined method. *Int Orthop.* 2011 Aug;**35**(8):1251-6
8. Kruger J, Carlson S. Trends in Strength Training --- United States, 1998--2004. *MMWR*. July 21, 2006 / **55**(28);769-772
9. Lauerson JB, Bertlesen DM, Andersen LB. The effectiveness of exercise interventions to prevent sports injuries: a systematic review and meta-analysis of randomised controlled trials. *Br J Sports Med*. 2014 Jun;**48**(11):871-7.
10. Lauerson JB, Andersen TE, Andersen LB. Strength training as superior, dose-dependent and safe prevention of acute and overuse sports injuries: a systematic review, qualitative analysis and meta-analysis. *Br J Sports Med.* 2018 Dec;**52**(24):1557-1563.

11. Layne JE, Nelson ME.The effects of progressive resistance training on bone density: a review. *Med Sci Sports Exerc* 1999 Jan;**31**(1):25-30.
12. Lipps DB, Oh Y, Ashton-Miller JA, *et al*. The Effect of ACL Cross-Sectional Area on ACL Strain Under Compound Impulsive Loading. *ORS 2011 Annual Meeting*.
13. Lloyd RS, Feigenbaum AD, Stone MH, *et al*. Position Statement on Youth Resistance Training: the 2014 International Consensus. *British Journal of Sports Medicine* 2014; **48**:498-505.
14. Ram Hong A, Wang Kim Sam. Effects of Resistance Exercise on Bone Health. *Endocrinol Metab(Seoul).* 2018 Dec; **33**(4): 435–444.
15. Renstrom P, Ljungqvist A, Arendt E. Non-Contact ACL Injuries in female athletes: an International Olympic Committee Current Concepts Statement. *British Journal of Sports Medicine* 2008;**42:**394-412.
16. Shoenfield B, Petersen MD, Ogborn D, *et al*. Effects of Low- vs. High-Load Resistance Training on Muscle Strength and Hypertrophy in Well-Trained Men. *J Strength Cond Res* 2015 Oct;**29**(10):2954-63.
17. Steffen K, Nilstad A, Kristianslund EK, Myklebust G, *et al.* Association between Lower Extremity Muscle Strength and Noncontact ACL Injuries. Med Sci Sports Exerc. 2016 Nov;**48**(11):2082-2089.
18. Steib S, Rahlf A, Pfeifer K, Zech A. Dose-Response Relationship of Neuromuscular Training for Injury Prevention in Youth Athletes: A Meta-Analysis. Front Physiol. 2017; **8**: 920.
19. Sugimoto D, Myer GD, Foss KD, Hewett TE. Specific exercise effects of preventive neuromuscular training intervention on anterior cruciate ligament injury risk reduction in young females: meta-analysis and subgroup analysis.*Br J Sports Med.* 2015 Mar;**49**(5):282-9.

WITH YOU FROM BARBELL MEDICINE BENCH TO BEDSIDE