5-5-2017

Effects of Heavy Episodic Drinking on Muscle Quality in College Students

Allison G. Leggett
Loyola Marymount University, aleggett@lion.lmu.edu

LMU|LA
University Honors Program

Effects of Heavy Episodic Drinking on Muscle Quality in College Students

A thesis submitted in partial satisfaction

of the requirements of the University Honors Program

of Loyola Marymount University

by

Allison Leggett

May 2017

ACKNOWLEDGEMENTS

We would graciously like to acknowledge Loyola Marymount University and the Department of Health & Human Sciences, especially Hawley Almstedt, Danielle Good, and Caitlin Jennings, as well as the Department of Psychology, including members of the *HeadsUP!* research team such as Joseph LaBrie, Andrew Earl, Sarah Boyle, and Nicole Froidevaux. We would also like to acknowledge every student member of this research team and the 179 participants who volunteered for this study. The research used for this publication was funded by the National Institute on Alcohol Abuse And Alcoholism of the National Institutes of Health, under Award Number R21AA022942.

Table of Contents

Effects of Heavy Episodic Drinking on Muscle Quality in College Students

LEGGETT, ALLISON G. [1], SHOEPE, TODD C. [1], ALMSTEDT, HAWLEY, C. [1], LABRIE, JOSEPH W. [2]

From the Departments of Health and Human Sciences[1] and Psychology[2], Loyola Marymount University, Los Angeles, CA

ABSTRACT

College is a critical time in peak muscle mass development and evidence suggests heavy episodic drinking (HED), defined as four or more alcoholic drinks for females and five or more drinks for males in one sitting, may inhibit acute and chronic muscle remodeling. Muscle quality (MQ), or the strength per lean body mass, acts as an indicator of muscle performance and reflects the physiological, functional and structural composition of muscle tissue. The purpose of this study was to examine the acute and longitudinal effects of HED on MQ and other body compositional variables in college students. Methods: A total of 90 females (18.7±0.6 yrs; BMI 23.0±3.3 kg/m^2) and 89 males (18.7±0.7 yrs; BMI 22.9±2.6 kg/m^2) volunteered for this study. Regional body composition was assessed with dual-energy x-ray absorptiometry and MQ was determined by summing the maximal right and left handgrip strength divided by non-mineral lean mass of both arms. Acute effects were assessed for participants who self-reported HED in the 4-days prior to strength testing. Results: At baseline, males demonstrated a significantly (p<0.05) greater absolute HG (84.1±2.2 vs. 56.9±1.1 kg) and lower MQ (12.3±0.3 vs. 14.5±0.3 kg) than females. At 6 months, males exhibited a significantly greater lean arm mass (7.2±0.2 vs. 6.7±0.1 kg) and trended towards a greater lean body mass (60.9±1.2 vs. 57.8±0.7 kg) in the acute HED group compared to the LED group. These findings suggest a potential sex difference, with

females demonstrating a greater MQ than males, despite having a lower maximal grip strength. Furthermore, it appears that an instance of HED is associated with a higher muscle mass in males. A longer longitudinal investigation with an emphasis on increased patterns of HED is necessary to further examine its potential effects.

INTRODUCTION

Heavy episodic drinking (HED), more commonly known as binge drinking, has been recognized as a serious public health concern across college campuses (R. Hingson, Heeren, Winter, & Wechsler, 2005). Despite many preventative efforts to increase education about the associated risks, in the United States, it is estimated that two out of five college students engage in HED on a regular basis (Wechsler, Davenport, Dowdall, Moeykens, & Castillo, 1994). A survey conducted on 140 college campuses found that while approximately 44% of the population of college students reported HED occurrences, only 16% abstained from drinking entirely (Wechsler et al., 1994; Wechsler, Kelley, Weitzman, SanGiovanni, & Seibring, 2000). The frequency of this behavior poses significant risks to the drinkers and the surrounding environment. HED can incite a myriad of immediate, negative consequences, including decreased academic performance, and increased incidences of physical assault and infractions with law enforcement (O'Malley & Johnston, 2002; Wechsler et al., 1994). It is estimated that approximately 500,000 students annually are subjected to unintentional harm as a result of alcohol usage (R. Hingson et al., 2005). In 2005, alcohol consumption contributed to 1,825 fatal injuries including alcohol poisoning, automobile collisions, drownings, and falls (Ham & Hope, 2003; R. W. Hingson, Zha, & Weitzman, 2009). Thus, HED is the leading cause of death among college-aged individuals, between 17-24 years (R. Hingson et al., 2005; Perkins, 2002).

Over the long term, heavy alcohol consumption has been shown to influence body composition. In one study, Maddalozzo et al. found that rats who were fed a liquid alcohol diet for approximately three months, to mimic chronic alcohol consumption, presented with lower lean mass, fat mass and bone mineral density (Maddalozzo et al., 2009). Fat mass and overall body mass is directly related to both bone and muscle strength (Maddalozzo et al., 2009). Previous research has demonstrated that chronic alcohol consumers are often affected by chronic alcoholic myopathy—a condition marked by the progressive weakening and loss of muscle mass and function—which affects approximately 50% of alcoholics (Preedy et al., 2001). Furthermore, substantial research has suggested that excess alcohol consumption negatively impacts bone health, by decreasing bone mineral density and increasing the fracture risk associated with osteoporosis (Kanis et al., 2005; Seeman, Melton, O'Fallon, & Riggs, 1983). Although the clear mechanism of the effect is still being studied, it is suggested that heavy alcohol consumption, that is initiated around late adolescence, is associated with the most significant effects on bone mineral density (Maddalozzo et al., 2009). Concurrently, when compared to drinking patterns throughout life, HED incidents occur most between the ages of 18-25 years, a period of time marking the transition between high school and college (Greenfield, Midanik, & Rogers, 2000; Kandel & Logan, 1984; Yusko, Buckman, White, & Pandina, 2008). This is particularly concerning, due to the innate interconnectivity between bone and muscle mass, which respond similarly to environmental changes, including weight-bearing activity, smoking, oral contraceptive pill usage and alcohol consumption (Arden & Spector, 1997). If a noticeable effect is visible in bone mineral density at a young age, it is possible that heavy alcohol consumption could negatively impede an individual from reaching his/her optimal mass.

Muscle mass growth peaks around 20 and 30 years of age, at which point it begins to decrease (Frost, Nielsen, Brixen, & Andersen, 2015; Janssen, 2010). Thus, this period of heavy alcohol consumption appears to coincide with a crucial time at which individuals reach peak muscle mass and function, which sets the foundation for muscle capacity later on in life. Over time, muscle mass and function naturally decline, which is a term known as sarcopenia. By definition, sarcopenic individuals are two standard deviations below the mean muscle mass of young adults, even after their muscle mass is adjusted to consider height and weight (Janssen, 2010). The entire older adult population has varying degrees of sarcopenia, some more severe than others. The term Muscle Quality (MQ), which is an important variable used to assess muscle efficiency by adjusting for body mass differences, provides insight into the various degrees that neuromuscular factors and muscle hypertrophy influence muscle strength and composition (Barbat-Artigas, Rolland, Zamboni, & Aubertin-Leheudre, 2012). It is defined as the force per unit of muscle mass. Although, the age-related effects of aging on MQ are still under investigation, Lynch et al. observed a lower MQ in the older adult population, suggesting a potential age-related decline (Lynch et al., 1999). According to Thompson et. al., individuals begin to demonstrate declines in arm and leg strength at a rate of 8% per decade at the age of 30 years; this rate increases to approximately 20-40% annually by the age of 70-80 years (Thompson, 2002).

These age-associated changes in muscle mass, strength, and quality cannot simply be avoided by increasing lean mass through activity (Goodpaster et al., 2006). However, regular exercise and strength training can lower the rate of these natural declines in motor performance (Tracy et al., 1999). Although sarcopenia may not be an immediate problem for college-aged students, it could have detrimental effects in the long-term, by decreasing quality of life. Sarcopenia in the older adult population increases the likelihood of functional impairment, such that affected individuals are four times more likely to have a physical disability than those with a ‘normal’ muscle mass and strength (Janssen, 2010). Thus, behavior during the formative, young-adult years is crucial to establishing long-term health status. Previous research on the young-adult population has mainly focused on the acute effects of alcohol consumption on muscle recovery after exercise (Barnes, Mundel, & Stannard, 2010, 2012; Clarkson & Reichsman, 1990); however, to our knowledge, little has been done to explore the long-term effects of heavy alcohol consumption on MQ. The aim of this present research study is to examine both the acute and longitudinal effects of HED on MQ and body composition in the young adult population.

METHODS

STUDY POPULATION

Participants were 179 undergraduates [90 females (18.7±0.6 yrs) and 89 males (18.7±0.7 yrs)] at Loyola Marymount University, and were recruited via random and quota sampling. A list of 900 random freshman and sophomore students was provided by the university's registrar, who were contacted via email and invited to participate in the study. Those students were then screened to ensure their eligibility; individuals between the ages of 18-21 years, with a self-reported BMI between 18.5 and 30 kg/m^2 and either zero or $\geq$ 2 HED events within the last month, were then selected for participation. Students were then divided into four groups based on their gender and reported alcohol consumption: light episodic drinking (LED) females, LED males, HED females, and HED males. The participant pool included a diverse selection of races, in adherence with the National Institutes of Health objectives of inclusion in human research. Baseline physical characteristics of the participants can be found in Table 1.

ALCOHOL CONSUMPTION

HED or "binge" drinking is defined in association with previous standards as having 5 or more drinks for males and 4 or more drinks for females in one sitting (O'Malley & Johnston, 2002; Wechsler et al., 1994). Females exhibit alcohol-related problems at lower levels of consumption—even after accounting for body mass. This is primarily due to an inherent gender difference in alcohol metabolism that results in higher blood alcohol levels at fixed rates (Frezza et al., 1990). Baseline values of alcohol consumption were determined using the 2014 Block Food Frequency Questionnaire; estimated lifetime HED occurrences over the previous six months were averaged to determine the rate of HEDs per week. The top 20^{th} percent of alcohol consumers were placed in the HED group while the remaining 80^{th} percent of participants were placed in the LED group. In addition, acute alcohol consumption—which was classified as HED within the four days preceding testing—was measured on site prior to testing at

6 months.

BODY COMPOSITION

Regional body composition was assessed with dual-energy x-ray absorptiometry (DXA; Hologic Discovery A; Waltham, MA, USA) where non-mineral lean body mass and lean arm mass variables were obtained from a supine, whole-body (WB) scan. Total MQ, lean muscle mass in the arm, WB lean mass, WB fat mass, and WB percent fat, which have all been impacted by alcohol consumption in previous research studies, were measured (Maddalozzo et al., 2009). All scans were done by two licensed and trained individuals, following standardized external and internal guidelines. The scans were then analyzed by two individuals, who also aligned with standard protocol. Height was measured to the nearest 0.5 cm using a stadiometer. Weight was measured to the nearest 0.1 kg using a traditional digital scale, with participants wearing light clothing and no shoes. For each measurement, two values were recorded and then averaged to provide the best estimate. Participants were measured at baseline (February – March 2016) and at approximately 6 months (September – November 2016).

MUSCULAR PERFORMANCE

Muscle strength was determined using a handgrip dynamometer (Takei Physical Fitness Test Grip-D, Takes Scientific Instruments, Co., Ltd, Niigata City, Japan). HG strength is a simple and standardized method of measuring whole body strength in clinical settings (Roberts et al., 2011). Participants performed the HG test with arms positioned by the body’s side and hand in a neutral grip. Values were obtained at both baseline and 6 months. For each time point, three values were recorded—separated by 1 minute to account for possible fatigue—and the highest from each hand was selected in the analysis as an indicator of maximal strength. Dynamometer settings were established based on hand sizes and kept consistent across the different time points. MQ was calculated by summing the maximal right and left HG strength divided by non-mineral lean mass of both arms. Longitudinal performance was assessed using a collection of lifetime resistance training (RT), which was determined via a bone-specific physical activity questionnaire (BPAQ). Weight-lifting and physical activity have been shown to influence body composition in previous studies (Kraemer & Ratamess, 2004; W. C. Miller, Lindeman, Wallace, & Niederpruem, 1990). The questionnaire responses were used to calculate metabolic equivalents of tasks (METs), as a means of assessing the overall energy cost of the physical activities performed.

STATISTICAL ANALYSIS

The statistical analysis was conducted utilizing SPSS software version 22 (IBM Corp., Armonk, NY). A 2-way multivariate ANCOVA was conducted for acute, cross-sectional effects of HED and a 2-way repeated measures ANCOVA was conducted for longitudinal effects on body composition and muscular performance, with p-values set at < 0.05 for significance. Alcohol consumption was regarded as the independent variable. Participants were divided into the previously mentioned four groups, based on gender and alcohol consumption. The six dependent variables measured were combined HG strength, combined lean muscle mass in the arm, total MQ, whole body (WB) lean mass, WB total fat mass, and WB percent fat. Height, weight-lifting (no, light, heavy), physical activity, and daily caloric intake, were also included as covariates in this analysis, which have been shown to influence body composition (Hagberg et al., 2000; Kraemer & Ratamess, 2004; W. C. Miller et al., 1990).

RESULTS

GENDER COMPARISONS AT BASELINE

Baseline physical characteristics of the participants is provided in Table 1. At baseline, males exhibited a significantly greater height and weight ($p < 0.01$) than females (n = 179). Females demonstrated a significantly greater % Body fat compared to males. A visual representation of these results can be found in Figures 1 and 2. Males demonstrated a significantly greater ($p < 0.05$) absolute HG and lower MQ than females (Table 2 and Figure 2).

TABLE 1: Baseline Physical Characteristics of Participants

Variable	Male ($N = 89$)	Female ($N = 90$)
Age (y)	18.7 ± 0.7	18.7 ± 0.6
Height (cm)	178.1 ± 7.3	164.1 ± 6.4*
Weight (kg)	72.7 ± 9.4	62.1 ± 10.1*
Body Mass Index (kg/m^2)	22.9 ± 2.6	23.0 ± 3.3
Percent Body Fat (%)	20.6 ± 4.7	31.5 ± 5.1*

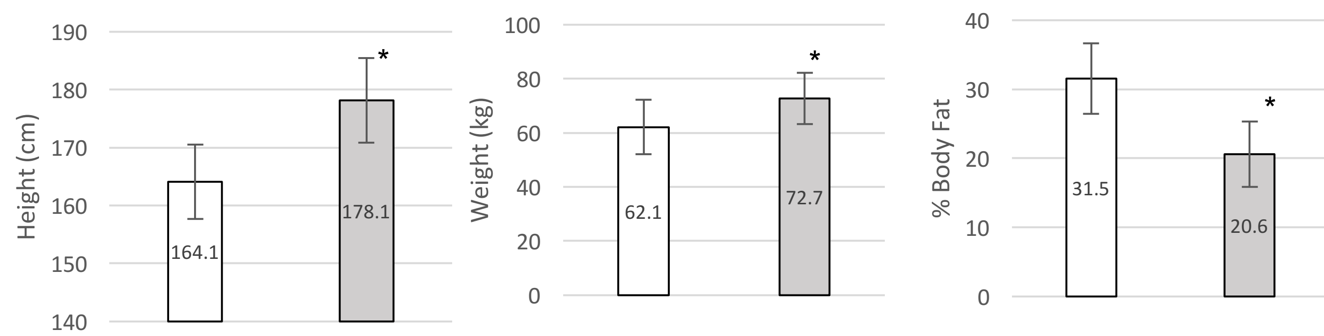
Notes: Data shown as Mean ± SD
*Significantly different between males and females: $p < 0.01$.

TABLE 2: Baseline measurements of Body composition of the Participants

	Males			Females		
Variable	HED (n = 12)	LED (n = 67)	Total (n = 79)	HED (n = 19)	LED (n = 63)	Total (n = 82)
Strength (kg)	85.0 ± 4.1	83.1 ± 1.7	84.1 ± 2.2	55.9 ± 2.1	57.8 ± 1.1	56.9 ± 1.1*
MQ (kg)	12.0 ± 0.5	12.7 ± 0.2	12.3 ± 0.3*	14.5 ± 0.5	14.6 ± 0.3	14.5 ± 0.3*
Total arm lean mass (kg)	7.2 ± 0.3	6.6 ± 0.1	6.9 ± 0.1	3.9 ± 0.1	4.0 ± 0.06	3.9 ± 0.1
WB lean mass (kg)	60.5 ± 1.6	57.4 ± 0.6	58.9 ± 0.8	41.9 ± 0.8	42.9 ± 0.4	42.4 ± 0.4
WB fat mass (kg)	15.4 ± 1.3	15.3 ± 0.5	15.3 ± 0.7	17.9 ± 1.4	20.6 ± 0.7	19.3 ± 0.7
WB percent fat (%)	20.2 ± 1.3	20.8 ± 0.5	20.5 ± 0.7	29.8 ± 1.2	31.8 ± 0.6	30.8 ± 0.7

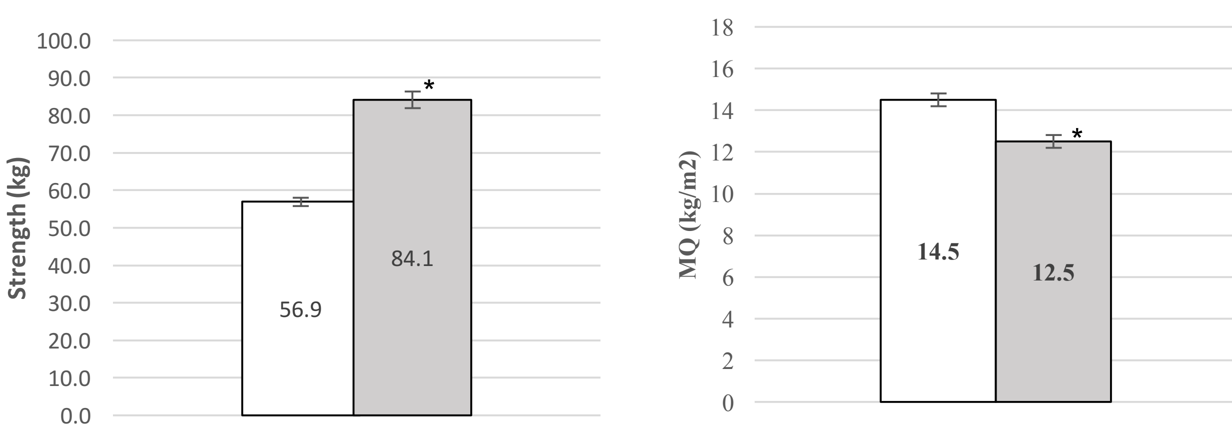
Notes: Data shown as Mean ± SE
*Significantly different between males and females: $p < 0.01$.

FIGURE 1A | Left: Height versus Gender
FIGURE 1B | Middle: Weight versus Gender
FIGURE 1C | Right: Percent Body Fat versus Gender



Significant difference between men and women: *$p < 0.01$; Males obtained a greater height and weight, but lower body fat compared to females.

FIGURE 2A | Left: Combined Grip Strength of the Right and Left Hand versus Gender
FIGURE 2B | Right: Muscle Quality versus Gender



Significant difference between men and women: *$p < 0.01$; Females demonstrated a lower absolute grip strength but greater MQ

LONGITUDINAL ALCOHOL EFFECTS

It appeared as though males with a greater history of HED trended towards a greater strength, lean arm mass, and WB lean compared to those reporting LED, but these results were not significant (Table 2). In contrast, females who reported a history of HED trended towards a lower MQ than those reporting LED, which was not significant. The females in this group also demonstrated lower strength, higher WB fat mass, and higher percent body fat, compared to the LED group, that approached significance.

LONGITUDINAL CHANGES IN BODY COMPOSITION

Over the 6-month period, the combined group exhibited significant increases in strength, MQ, and WB lean; simultaneously, WB percent fat decreased significantly over the timeframe (Table 3 and Table 4). The percent difference between visit 1 and visit 2 is illustrated in Figure 4.

TABLE 3: Measurements of body composition for participants at visit 2

	Males			Females		
Variable	HED (n = 12)	LED (n = 67)	Total (n = 79)	HED (n = 19)	LED (n = 63)	Total (n = 82)
Strength (kg)	86.2 ± 3.7	85.1 ± 1.5	85.7 ± 2.0	58.0 ± 2.3	58.3 ± 1.2	58.1 ± 1.3
MQ (kg)	12.1 ± 0.5	12.9 ± 0.2	12.5 ± 0.3	14.9 ± 0.6	14.8 ± 0.3	14.8 ± 0.3
Total arm lean mass (kg)	7.3 ± 0.3	6.7 ± 0.1*	7.0 ± 0.1	3.9 ± 0.1	4.0 ± 0.1	4.0 ± 0.1
WB lean mass (kg)	61.9 ± 1.6	57.9 ± 0.7**	59.9 ± 0.9	42.2 ± 0.8	43.1 ± 0.4	42.6 ± 0.4
WB fat mass (kg)	15.8 ± 1.3	14.7 ± 0.5	15.2 ± 0.7	17.9 ± 1.4	20.1 ± 0.7	19.1 ± 0.8
WB percent fat (kg)	20.1 ± 1.3	20.1 ± 0.5	20.1 ± 0.7	29.6 ± 1.3	31.2 ± 0.7	30.4 ± 0.7

Notes: Data shown as Mean ± SE
Significantly different between HED and LED groups: *$p < 0.05$, ** indicates close to significance

TABLE 4: Change in measurements of Body composition from visit 1 to 2 for combined group

Variable	Visit 1	Visit 2	% Difference	Significance
Height (cm)	171.1 ± 0.5	170.8 ± 0.5	-0.2	$p < 0.05$
Weight (kg)	67.4 ± 0.7	67.6 ± 0.8	+0.3	$p = 0.35$
BMI (kg/m^2)	23.0 ± 0.2	23.1 ± 0.2	+0.4	$p = 0.05$
Strength (kg)	71.7 ± 1.1	73.2 ± 1.1	+2.1	$p < 0.01$
MQ (kg)	13.4 ± 0.2	13.7 ± 0.2	+2.2	$p < 0.05$
Total arm percent fat (%)	26.4 ± 0.6	25.9 ± 0.6	-1.9	$p < 0.01$
Total arm lean mass (kg)	5.5 ± 0.8	5.6 ± 0.8	+1.8	$p = 0.37$
WB percent fat (%)	25.4 ± 0.5	24.9 ± 0.5	-2.0	$p < 0.01$
WB lean mass (kg)	51.1 ± 0.4	51.6 ± 0.4	+1.0	$p < 0.01$

Notes: Data shown as Mean ± SE; over the 6-months, height, weight, BMI, Strength, MQ, total arm lean mass, and WB lean mass increased, while total arm percent fat, and WB percent fat decreased.

FIGURE 3 | Relationship between Alcohol consumption and body composition

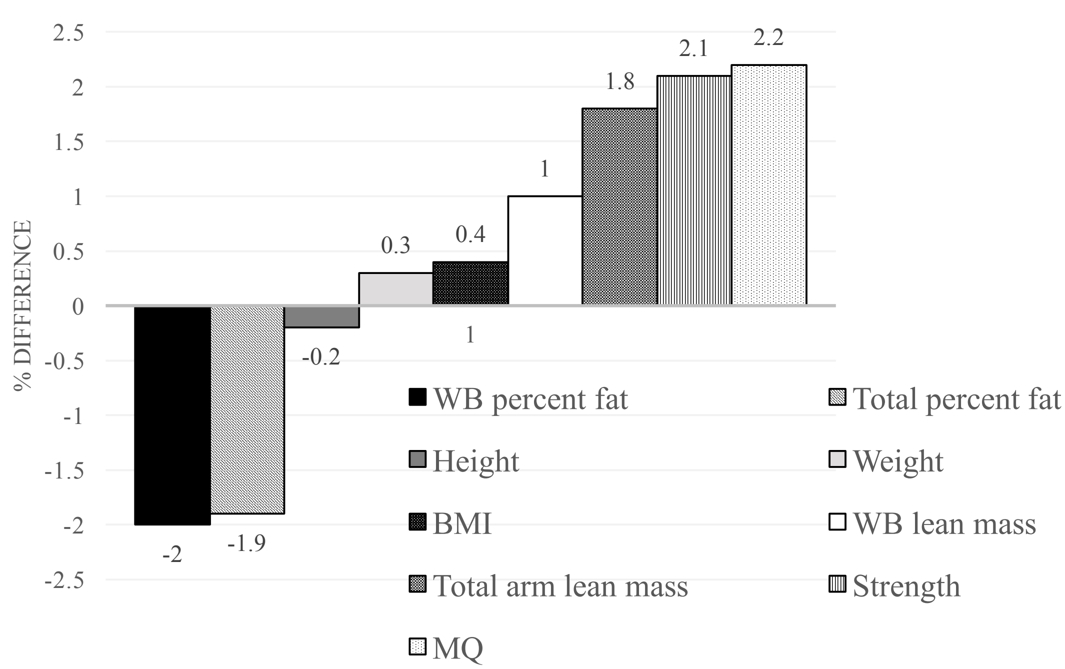


TABLE 5: Changes in lifestyle habits from visit 1 to visit 2

	Male (n = 80)		Female (n = 82)	
Variable	Visit 1	Visit 2	Visit 1	Visit 2
Total MET-hours $week^{-1}$	48.1 ± 10.4	54.1 ± 7.7	52.0 ± 6.4	47.8 ± 6.2
Estimated kcal day^{-1}	536.5 ± 115.6	611.3 ± 92.3	522.2 ± 70.1	463.0 ± 58.5

Notes: Data shown as Mean ± SE

TABLE 6: Acute effects of alcohol on body composition

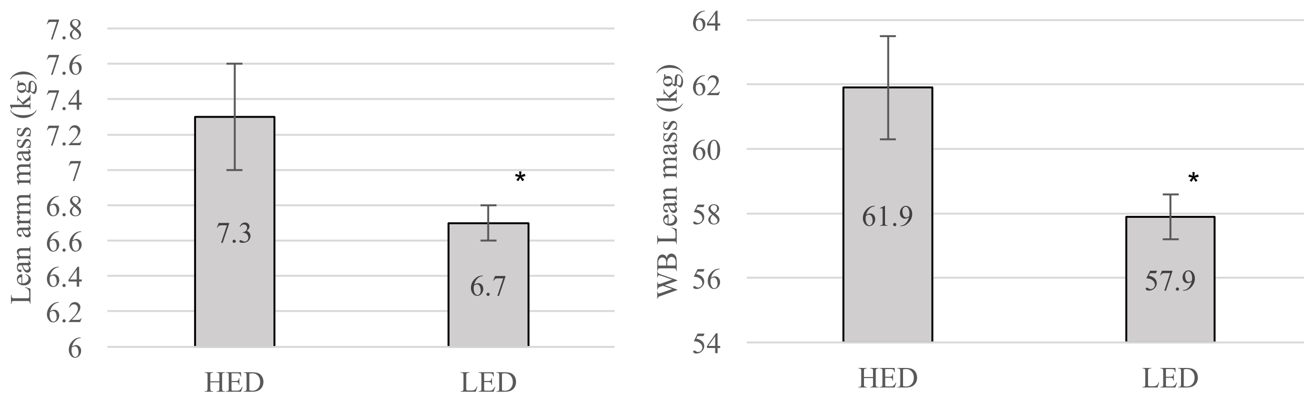
	Male (n = 80)		Female (n = 82)	
Variable	HED (n = 21)	LED (n = 59)	HED (n = 15)	LED (n = 67)
Strength (kg)	89.5 ± 2.8	84.6 ± 1.6	56.4 ± 2.4	58.2 ± 1.1
MQ (kg)	12.6 ± 0.4	12.9 ± 0.2	14.2 ± 0.6	14.9 ± 0.3
Total arm lean mass (kg)	7.2 ± 0.2	6.7 ± 0.1*	3.9 ± 0.1	3.9 ± 0.1
WB percent fat (%)	19.6 ± 1.0	20.1 ± 0.6	32.0 ± 1.4	30.7 ± 0.7
WB lean mass (kg)	60.9 ± 1.2	57.8 ± 0.7**	43.0 ± 0.9	42.8 ± 0.4
WB fat mass (kg)	15.0 ± 1.0	14.7 ± 0.60	20.5 ± 1.6	19.5 ± 0.7

Notes: Data shown as Mean ± SE
Significantly different between HED and LED groups: *$p < 0.05$, ** approaches significance

ACUTE ALCOHOL EFFECT

At 6 months, males exhibited a significantly greater total lean arm mass in the acute HED group compared to the LED group (Table 6 and Figure 4). WB lean mass also appeared greater in the HED group, which approached significance. Furthermore, the males in the acute HED group trended towards greater strength, and WB % fat, and lower MQ, but these results were also not significant. The females in the acute HED group trended towards lower strength and MQ, as well as greater WB lean mass, lean arm mass, and WB % fat when compared to the LED group, but these results were not significant.

FIGURE 4A | Left: Lean arm mass in males versus alcohol consumption
FIGURE 4B | Right: WB Lean mass in males versus alcohol consumption



DISCUSSION

This research study examined the potential acute and longitudinal effects of alcohol consumption on MQ and body composition in the college-age population. Findings suggest an inherent gender difference at baseline, with males demonstrating a lower MQ despite having a greater maximal grip strength. In prior studies, males have been shown to have a larger muscle mass than females—which allows them to produce a greater absolute force due to the interconnectivity between muscle mass and strength (Kanehisa, Ikegawa, Tsunoda, & Fukunaga, 1994; Leyk et al., 2007). Females typically exhibit significantly lower strength, often obtaining strength values that are 52% of the upper body and 66% of the lower body strength of males (A. E. Miller, MacDougall, Tarnopolsky, & Sale, 1993). This gender difference in hand-grip strength is even evident when comparing female athletes and non-athletic young men (Leyk et al., 2007).

Gender differences are more apparent when comparing upper body muscles, as a result of gender-specific variations in lean body mass distribution (A. E. Miller et al., 1993). However, to control for muscle mass differences, MQ was used in this study as a means of reflecting the physiological, functional and structural composition of muscle. Our results revealed a statistically higher MQ in females than males, which suggests that females might have a greater force production per unit of muscle mass. This finding contradicts what was illustrated in previous research on the matter. In a study by Frontera et al., when strength was adjusted for total body fat-free mass, males were still significantly stronger in the upper body, with no apparent gender differences in the lower body (Frontera, Hughes, Lutz, & Evans, 1991). Another study by Lynch et al., found that when testing young and older adult individuals for strength, males obtained significantly greater MQ in both arms and legs (Lynch et al., 1999). However, studies have suggested that even though significant differences in strength may exist, MQ is approximately the same across genders at both young and older age (Kent-Braun & Ng, 1999; A. E. Miller et al., 1993).

Our finding does, however, parallel that in a study performed by Ivey et. al, which compared the effects of strength training on MQ between sexes. In this study, 11 young men (20-30 yrs), 11 older men (65-75 yrs), 9 young women (20-30 yrs), and 11 older women (65-75 yrs) were given a 9-week unilateral strength training program on the knee extensors of their dominant leg, followed by a 31-week detraining program. At the end of the study, all groups showed an increase in 1RM strength and muscle volume. However, the increases were significantly greater in young women (Ivey et al., 2000). Even though this study implemented a strength training program, it suggests the possibility that there are other factors, besides muscle mass, that play a role in strength and MQ.

One possible factor that influences the strength and MQ dichotomy between the sexes is muscle composition, particularly dealing with muscle fiber types. Men have reportedly been known to have greater absolute cross-sectional area of the three types of fiber including types I, IIA, and IIB (Malisoux, Francaux, Nielens, & Theisen, 2006) in the vastus lateralis muscle—with type IIA constituting the largest value (Staron et al., 2000). Fast-twitch muscle fibers, which includes type IIA fibers, contribute to greater power production, largely due to their capacity for exercise-induced hypertrophy and quick contraction time, compared to slow-twitch fibers (Hautier, Linossier, Belli, Lacour, & Arsac, 1996) Fast-twitch muscle fibers are able to engage in quicker neural activation, leading to action potentials that increase force production (Moritani & deVries, 1979). This information explains why males might produce greater absolute strength than females, given their greater concentration of anaerobically-favored type II fibers. Even though this fiber type differentiation is more prominent in the lower body, it is still possible that there are differences in fiber type distribution that contribute to the notable gender difference. When that absolute strength is controlled for larger CSA or muscle mass, this would justify the smaller MQ in males compared to females.

Another factor that might contribute to gender differences in MQ is the electrical activation of the muscles involved in the action (Rutherford & Jones, 1986). Maximal muscular contraction and force production rely on adequate neural activation of the muscle. Neural activation can be hindered by ineffective fast motor unit recruitment—which require high forces that are not yielded in an inexperienced individual—and the inability to generate complete electrical stimulation at the necessary frequencies (Jones, Rutherford, & Parker, 1989). In addition, in the inexperienced individual, co-contraction of agonist and antagonist muscles are more common and could limit force production by inhibiting reciprocal inhibition. When an agonist muscle contracts, the opposing muscle, also known as the antagonist, relaxes to allow for full contraction. Co-contraction is often a problem in novice individuals, that generally disappears as the individual matures. This results in an improvement in neural activation, which manifests as improvements in strength. Thus, as individuals mature, their neural activation would naturally improve and result in a more efficient muscle contraction. Females, who naturally grow at a faster rate than males, could potentially reach this muscle capacity at a younger age than males (Hagg & Taranger, 1982); thus, they would present with greater neural activation for force production. In contrast, males might have inadequate neural activation—which means poor fast motor unit recruitment and a greater incidence of co-contraction—even if they are able to produce a greater absolute force due to their mass. Essentially, this would result in females having a greater MQ, thus explaining our finding.

The differences between our results and previous studies evaluating MQ could be due to the different techniques used to measure lean body mass. Many factors, including cost and ease of use could influence which technique is used for body composition measurements. Many studies have used magnetic resonance imaging (MRI) (Kent-Braun & Ng, 1999), computerized tomography (CT) (A. E. Miller et al., 1993), hydro-densitometry, and creatinine excretion (Frontera et al., 1991) to measure lean body mass. Out of the techniques used, the four-compartment model is viewed as the golden standard because it is able to account for individual variability in lean body mass composition and is able to separate water and mineral mass from the lean mass (Fuller, Jebb, Laskey, Coward, & Elia, 1992). In our study, a DXA scan was utilized to estimate non-mineral lean body mass and other body composition variables, due to its accessibility and ease of use in the clinical setting; this technique is generally a well-established alternative to measuring lean mass (Chen et al., 2007). Despite the variations in techniques used, it is clear that the topic of possible gender differences in MQ is still debatable and that our unique finding warrants further investigation.

An additional finding from this study was that it appeared the combined group of subjects got more lean over the course of the 6-month period. This might be a reflection of normal changes that occur during the transition between freshman and sophomore year. During the first year of college, it is common from individuals to experience notable weight gain, a situation commonly referred to as the Freshman Fifteen (Levitsky, Halbmaier, & Mrdjenovic, 2004). However, one study by Lloyd-Richardson et al., which evaluated the changes in weight over the course of the first two years of college, found that a majority of students gained weight in the first semester—50% of which lost weight during the second semester (Lloyd-Richardson, Bailey, Fava, & Wing, 2009). The transition into college is marked by significant changes in lifestyle, that often lead to poor health choices and substantial weight gain. Nevertheless, this rapid rate of weight gain does not continue over the course of the four years (Racette, Deusinger, Strube, Highstein, & Deusinger, 2008), although it might increase slightly. It is possible that as individuals transitioned into their sophomore year, potentially moving off campus and gaining access to a large variety of food, they adapted healthier lifestyles, thus promoting the apparent positive changes in body composition.

Furthermore, a potential, acute alcohol effect was uncovered in males, with those who engaged in HED (≤ 4 days prior to testing) demonstrating an elevated lean arm and lean body mass. This finding goes against previous research that suggests that at high alcohol consumption—levels greater than 56 grams of ethanol—individuals show decreases in weight due to the loss of lean mass (Duane & Peters, 1988). In our study, it is plausible that the DXA scan used for body composition measurements could have erroneously determined lean mass. A DXA scan works by way of a three-component model, separating mineral, non-mineral, and fat mass; all other soft-lean tissue is assumed to have a hydration of 73 g/mL (Prior, Cureton, Modlesky, Evans, Sloniger, Saunders, & Lewis, 1997). Because the DXA relies on this assumption, any alteration in body water concentration could potentially skew the results for lean tissue. This possible hydration effect is an important factor to consider due to the natural shifts in water as a result of alcohol consumption, specifically the prevalence of alcohol-induced diuresis (Hobson & Maughan, 2010). On the acute level, alcohol consumption initiates a cascade of biochemical effects that eventually leads to the oversecretion of water. When alcohol is consumed, works by depressing the secretion of vasopressin from the posterior pituitary gland. Vasopressin, also known as antidiuretic hormone, is responsible for managing osmolality in body fluids by retaining or excreting fluids as needed. As a result, shortly after alcohol consumption, an individual experiences increased urine production or diuresis (Eisenhofer & Johnson, 1982; Hobson & Maughan, 2010). However, one animal study by Essig et al. found a possible rebound effect that can occur during alcohol withdrawal (Essig, 1968). Rats were given a diet of approximately 20% alcohol for 4 days. During the first day of withdrawal, the rats consumed a significantly greater amount of water, compared to the control; this water consumption decreased over the next few days and began to increase again after the fourth day. To our knowledge, few research is available on the extent of water consumption following alcohol intake. However, the results of this animal study suggest that water consumption could increase significantly in the days succeeding alcohol intake. In our study, we measured acute alcohol consumption as HED in the four days prior to testing. The individuals who engaged in acute HED might have experienced a rebound effect, where they consumed more water in the days following consumption; this might, in turn, lead to more water retention, which could have been incorrectly measured as lean mass by the DXA machine. Although the potential sources of error are still under investigation (Lohman, Harris, Teixeira, & Weiss, 2000), this is an important factor to be considered when analyzing our results.

Furthermore, another factor that could have influenced the acute effects in lean mass is physical activity. Higher physical activity levels are associated with decreased percent body fat values and increased lean body mass (Hagberg et al., 2000). In particular, resistance training is known to positively influence body composition, by increasing muscle strength, hypertrophy, local muscular endurance, and lean body mass, while also decreasing percent fat mass (Kraemer & Ratamess, 2004). Individuals in the acute HED group might be engaging in more resistance training, which would explain the increases in lean mass. Additionally, it is plausible that social norms might have also impacted body composition. According to Wallace et al., social support is good indicator of a student's participation in physical activity; in fact, while females are more influenced by family social support, males appear to be more influenced by peer support (Wallace, Buckworth, Kirby, & Sherman, 2000). Individuals who engage in acute HED could also be encouraged by peers to engage in other behaviors that might positively influence body composition—such as diet and exercise (resistance training) (Barry & Piazza-Gardner, 2012) Diets consisting of less dietary fat and more complex carbohydrate and fiber consumption are positively associated with lower body fat and greater lean mass (Nelson & Tucker, 1996). Prior research has confirmed this theory, by uncovering an alcohol-activity association in which individuals who are very active are more likely to engage in HED than individuals who are less active (Barry & Piazza-Gardner, 2012). Therefore, it is highly likely that this association could have skewed our finding.

Overall, this research study revealed potential gender differences in both MQ and lean muscle mass distribution. Although males had a greater maximal grip strength, they had significantly lower MQ—possibly a result of muscle fiber differences and neuromuscular activation. In addition, males who reported acute HED demonstrated a significantly greater lean arm mass, and trended towards a greater WB lean mass. This study was innovative because it was the first of its kind to evaluate the relationship between HED and MQ in college-aged adults. State-of-the-art technology, including the DXA machine, was used to provide a quantitative measurement and evaluation of the changes in lean body mass over the course of the study for a large subject pool. This study explored the potential longitudinal and acute effects of alcohol consumption on MQ by looking at past history of HED (lifetime), evaluating whether MQ and body composition changes over the course of 6 months, and investigating whether acute HED before testing influences testing results. However, several limitations in the study design could have altered our results. First, Loyola Marymount is a private institution with access to a gym, that is equipped with a Fitwell center to guide students towards healthy lifestyle habits. In addition, the school prides itself in offering healthy options, produced from locally-grown foods. We also excluded individuals with a BMI that was greater than 30 $kg.m^2$, who would fall within the obese category. Thus, the data collected for body composition could be more representative of this private institution, rather than college students in general and could have potentially affected the results. Additionally, it is unclear whether the apparent acute effect on lean muscle mass reflects only an alcohol effect. In our statistical analysis, we chose the covariates, height, weight-lifting (no, light, heavy), physical activity, and daily caloric intake for our analysis, which had already been shown to influence body composition in previous studies (Hagberg et al., 2000; Kraemer & Ratamess, 2004; W. C. Miller et al., 1990; Nelson & Tucker, 1996). However, while analyzing the acute effects, we were unable to control for physical activity and resistance training. Thus, a longer longitudinal investigation with an emphasis on increased patterns of HED is necessary to further examine its effects.

REFERENCES

Arden, N. K., & Spector, T. D. (1997). Genetic influences on muscle strength, lean body mass, and bone mineral density: a twin study. *J Bone Miner Res, 12*(12), 2076-2081. doi:10.1359/jbmr.1997.12.12.2076

Barbat-Artigas, S., Rolland, Y., Zamboni, M., & Aubertin-Leheudre, M. (2012). How to assess functional status: a new muscle quality index. *J Nutr Health Aging, 16*(1), 67-77.

Barnes, M. J., Mundel, T., & Stannard, S. R. (2010). Acute alcohol consumption aggravates the decline in muscle performance following strenuous eccentric exercise. *J Sci Med Sport, 13*(1), 189-193. doi:10.1016/j.jsams.2008.12.627

Barnes, M. J., Mundel, T., & Stannard, S. R. (2012). The effects of acute alcohol consumption on recovery from a simulated rugby match. *J Sports Sci, 30*(3), 295-304. doi:10.1080/02640414.2011.637949

Barry, A. E., & Piazza-Gardner, A. K. (2012). Drunkorexia: understanding the co-occurrence of alcohol consumption and eating/exercise weight management behaviors. *J Am Coll Health, 60*(3), 236-243. doi:10.1080/07448481.2011.587487

Chen, Z., Wang, Z., Lohman, T., Heymsfield, S. B., Outwater, E., Nicholas, J. S., . . . Going, S. (2007). Dual-energy X-ray absorptiometry is a valid tool for assessing skeletal muscle mass in older women. *J Nutr, 137*(12), 2775-2780.

Clarkson, P. M., & Reichsman, F. (1990). The effect of ethanol on exercise-induced muscle damage. *J Stud Alcohol, 51*(1), 19-23.

Duane, P., & Peters, T. J. (1988). Nutritional status in alcoholics with and without chronic skeletal muscle myopathy. *Alcohol Alcohol, 23*(4), 271-277.

Eisenhofer, G., & Johnson, R. H. (1982). Effect of ethanol ingestion on plasma vasopressin and water balance in humans. *Am J Physiol, 242*(5), R522-527.

Essig, C. F. (1968). Increased water consumption following forced drinking of alcohol in rats. *Psychopharmacologia, 12*(4), 333-337.

Frezza, M., di Padova, C., Pozzato, G., Terpin, M., Baraona, E., & Lieber, C. S. (1990). High blood alcohol levels in women. The role of decreased gastric alcohol dehydrogenase activity and first-pass metabolism. *N Engl J Med, 322*(2), 95-99. doi:10.1056/nejm199001113220205

Frontera, W. R., Hughes, V. A., Lutz, K. J., & Evans, W. J. (1991). A cross-sectional study of muscle strength and mass in 45- to 78-yr-old men and women. *J Appl Physiol (1985), 71*(2), 644-650.

Frost, M., Nielsen, T. L., Brixen, K., & Andersen, M. (2015). Peak muscle mass in young men and sarcopenia in the ageing male. *Osteoporos Int, 26*(2), 749-756. doi:10.1007/s00198-014-2960-6

Fuller, N. J., Jebb, S. A., Laskey, M. A., Coward, W. A., & Elia, M. (1992). Four-component model for the assessment of body composition in humans: comparison with alternative methods, and evaluation of the density and hydration of fat-free mass. *Clin Sci (Lond), 82*(6), 687-693.

Goodpaster, B. H., Park, S. W., Harris, T. B., Kritchevsky, S. B., Nevitt, M., Schwartz, A. V., . . . Newman, A. B. (2006). The loss of skeletal muscle strength, mass, and quality in older adults: the health, aging and body composition study. *J Gerontol A Biol Sci Med Sci, 61*(10), 1059-1064.

Greenfield, T. K., Midanik, L. T., & Rogers, J. D. (2000). A 10-year national trend study of alcohol consumption, 1984-1995: is the period of declining drinking over? *Am J Public Health, 90*(1), 47-52.

Hagberg, J. M., Zmuda, J. M., McCole, S. D., Rodgers, K. S., Wilund, K. R., & Moore, G. E. (2000). Determinants of body composition in postmenopausal women. *J Gerontol A Biol Sci Med Sci, 55*(10), M607-612.

Hagg, U., & Taranger, J. (1982). Maturation indicators and the pubertal growth spurt. *Am J Orthod, 82*(4), 299-309.

Ham, L. S., & Hope, D. A. (2003). College students and problematic drinking: a review of the literature. *Clin Psychol Rev, 23*(5), 719-759.

Hautier, C. A., Linossier, M. T., Belli, A., Lacour, J. R., & Arsac, L. M. (1996). Optimal velocity for maximal power production in non-isokinetic cycling is related to muscle fibre type composition. *Eur J Appl Physiol Occup Physiol, 74*(1-2), 114-118.

Hingson, R., Heeren, T., Winter, M., & Wechsler, H. (2005). Magnitude of alcohol-related mortality and morbidity among U.S. college students ages 18-24: changes from 1998 to 2001. *Annu Rev Public Health, 26*, 259-279. doi:10.1146/annurev.publhealth.26.021304.144652

Hingson, R. W., Zha, W., & Weitzman, E. R. (2009). Magnitude of and trends in alcohol-related mortality and morbidity among U.S. college students ages 18-24, 1998-2005. *J Stud Alcohol Drugs Suppl*(16), 12-20.

Hobson, R. M., & Maughan, R. J. (2010). Hydration status and the diuretic action of a small dose of alcohol. *Alcohol Alcohol, 45*(4), 366-373. doi:10.1093/alcalc/agq029

Ivey, F. M., Tracy, B. L., Lemmer, J. T., NessAiver, M., Metter, E. J., Fozard, J. L., & Hurley, B. F. (2000). Effects of strength training and detraining on muscle quality: age and gender comparisons. *J Gerontol A Biol Sci Med Sci, 55*(3), B152-157; discussion B158-159.

Janssen, I. (2010). Evolution of sarcopenia research. *Appl Physiol Nutr Metab, 35*(5), 707-712. doi:10.1139/h10-067

Jones, D. A., Rutherford, O. M., & Parker, D. F. (1989). Physiological changes in skeletal muscle as a result of strength training. *Q J Exp Physiol, 74*(3), 233-256.

Kandel, D. B., & Logan, J. A. (1984). Patterns of drug use from adolescence to young adulthood: I. Periods of risk for initiation, continued use, and discontinuation. *Am J Public Health, 74*(7), 660-666.

Kanehisa, H., Ikegawa, S., Tsunoda, N., & Fukunaga, T. (1994). Cross-sectional areas of fat and muscle in limbs during growth and middle age. *Int J Sports Med, 15*(7), 420-425. doi:10.1055/s-2007-1021081

Kanis, J. A., Johansson, H., Johnell, O., Oden, A., De Laet, C., Eisman, J. A., . . . Tenenhouse, A. (2005). Alcohol intake as a risk factor for fracture. *Osteoporos Int, 16*(7), 737-742. doi:10.1007/s00198-004-1734-y

Kent-Braun, J. A., & Ng, A. V. (1999). Specific strength and voluntary muscle activation in young and elderly women and men. *J Appl Physiol (1985), 87*(1), 22-29.

Kraemer, W. J., & Ratamess, N. A. (2004). Fundamentals of resistance training: progression and exercise prescription. *Med Sci Sports Exerc, 36*(4), 674-688.

Levitsky, D. A., Halbmaier, C. A., & Mrdjenovic, G. (2004). The freshman weight gain: a model for the study of the epidemic of obesity. *Int J Obes Relat Metab Disord, 28*(11), 1435-1442. doi:10.1038/sj.ijo.0802776

Leyk, D., Gorges, W., Ridder, D., Wunderlich, M., Ruther, T., Sievert, A., & Essfeld, D. (2007). Hand-grip strength of young men, women and highly trained female athletes. *Eur J Appl Physiol, 99*(4), 415-421. doi:10.1007/s00421-006-0351-1

Lloyd-Richardson, E. E., Bailey, S., Fava, J. L., & Wing, R. (2009). A prospective study of weight gain during the college freshman and sophomore years. *Prev Med, 48*(3), 256-261. doi:10.1016/j.ypmed.2008.12.009

Lohman, T. G., Harris, M., Teixeira, P. J., & Weiss, L. (2000). Assessing body composition and changes in body composition. Another look at dual-energy X-ray absorptiometry. *Ann N Y Acad Sci, 904*, 45-54.

Lynch, N. A., Metter, E. J., Lindle, R. S., Fozard, J. L., Tobin, J. D., Roy, T. A., . . . Hurley, B. F. (1999). Muscle quality. I. Age-associated differences between arm and leg muscle groups. *J Appl Physiol (1985), 86*(1), 188-194.

Maddalozzo, G. F., Turner, R. T., Edwards, C. H., Howe, K. S., Widrick, J. J., Rosen, C. J., & Iwaniec,

U. T. (2009). Alcohol alters whole body composition, inhibits bone formation, and increases bone marrow adiposity in rats. *Osteoporos Int, 20*(9), 1529-1538. doi:10.1007/s00198-009-0836-y

Malisoux, L., Francaux, M., Nielens, H., & Theisen, D. (2006). Stretch-shortening cycle exercises: an effective training paradigm to enhance power output of human single muscle fibers. *J Appl Physiol (1985), 100*(3), 771-779. doi:10.1152/japplphysiol.01027.2005

Miller, A. E., MacDougall, J. D., Tarnopolsky, M. A., & Sale, D. G. (1993). Gender differences in strength and muscle fiber characteristics. *Eur J Appl Physiol Occup Physiol, 66*(3), 254-262.

Miller, W. C., Lindeman, A. K., Wallace, J., & Niederpruem, M. (1990). Diet composition, energy intake, and exercise in relation to body fat in men and women. *Am J Clin Nutr, 52*(3), 426-430.

Moritani, T., & deVries, H. A. (1979). Neural factors versus hypertrophy in the time course of muscle strength gain. *Am J Phys Med, 58*(3), 115-130.

Musselman, J. R., & Rutledge, P. C. (2010). The incongruous alcohol-activity association: Physical activity and alcohol consumption in college students. *Psychology of Sport and exercise*, *11*(6), 609-618.

Nelson, L. H., & Tucker, L. A. (1996). Diet composition related to body fat in a multivariate study of 203 men. *J Am Diet Assoc, 96*(8), 771-777. doi:10.1016/s0002-8223(96)00215-5

O'Malley, P. M., & Johnston, L. D. (2002). Epidemiology of alcohol and other drug use among American college students. *J Stud Alcohol Suppl*(14), 23-39.

Perkins, H. W. (2002). Surveying the damage: a review of research on consequences of alcohol misuse in college populations. *J Stud Alcohol Suppl*(14), 91-100.

Preedy, V. R., Adachi, J., Ueno, Y., Ahmed, S., Mantle, D., Mullatti, N., . . . Peters, T. J. (2001). Alcoholic skeletal muscle myopathy: definitions, features, contribution of neuropathy, impact and diagnosis. *Eur J Neurol, 8*(6), 677-687.

Prior, B. M., Cureton, K. J., Modlesky, C. M., Evans, E. M., Sloniger, M. A., Saunders, M., & Lewis, R. D. (1997). In vivo validation of whole body composition estimates from dual-energy X-ray absorptiometry. *Journal of applied physiology*, *83*(2), 623-630.

Racette, S. B., Deusinger, S. S., Strube, M. J., Highstein, G. R., & Deusinger, R. H. (2008). Changes in weight and health behaviors from freshman through senior year of college. *J Nutr Educ Behav, 40*(1), 39-42. doi:10.1016/j.jneb.2007.01.001

Roberts, H. C., Denison, H. J., Martin, H. J., Patel, H. P., Syddall, H., Cooper, C., & Sayer, A. A. (2011). A review of the measurement of grip strength in clinical and epidemiological studies: towards a standardised approach. *Age Ageing, 40*(4), 423-429. doi:10.1093/ageing/afr051

Rutherford, O. M., & Jones, D. A. (1986). The role of learning and coordination in strength training. *Eur J Appl Physiol Occup Physiol, 55*(1), 100-105.

Seeman, E., Melton, L. J., 3rd, O'Fallon, W. M., & Riggs, B. L. (1983). Risk factors for spinal osteoporosis in men. *Am J Med, 75*(6), 977-983.

Staron, R. S., Hagerman, F. C., Hikida, R. S., Murray, T. F., Hostler, D. P., Crill, M. T., . . . Toma, K. (2000). Fiber type composition of the vastus lateralis muscle of young men and women. *J Histochem Cytochem, 48*(5), 623-629. doi:10.1177/002215540004800506

Thompson, L. V. (2002). Skeletal muscle adaptations with age, inactivity, and therapeutic exercise. *J Orthop Sports Phys Ther, 32*(2), 44-57. doi:10.2519/jospt.2002.32.2.44

Tracy, B. L., Ivey, F. M., Hurlbut, D., Martel, G. F., Lemmer, J. T., Siegel, E. L., . . . Hurley, B. F. (1999). Muscle quality. II. Effects Of strength training in 65- to 75-yr-old men and women. *J Appl Physiol (1985), 86*(1), 195-201.

Wallace, L. S., Buckworth, J., Kirby, T. E., & Sherman, W. M. (2000). Characteristics of exercise behavior among college students: application of social cognitive theory to predicting stage of change. *Prev Med, 31*(5), 494-505. doi:10.1006/pmed.2000.0736

Wechsler, H., Davenport, A., Dowdall, G., Moeykens, B., & Castillo, S. (1994). Health and behavioral consequences of binge drinking in college. A national survey of students at 140 campuses. *Jama, 272*(21), 1672-1677.

Wechsler, H., Kelley, K., Weitzman, E. R., SanGiovanni, J. P., & Seibring, M. (2000). What colleges are doing about student binge drinking. A survey of college administrators. *J Am Coll Health, 48*(5), 219-226. doi:10.1080/07448480009599308

Yusko, D. A., Buckman, J. F., White, H. R., & Pandina, R. J. (2008). Alcohol, tobacco, illicit drugs, and performance enhancers: a comparison of use by college student athletes and nonathletes. *J Am Coll Health, 57*(3), 281-290. doi:10.3200/jach.57.3.281-290