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Changes in Overall Fitness in Response to Varying Ratios of Cardiovascular and Resistance Training

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Abstract:

Obesity prevalence is high among young adults (18 – 29 years of age). The goal of this study was to determine the effect of varying ratios of resistance and cardiovascular training on aerobic capacity, muscular strength, and anthropometric measurements in college students. For six weeks, participants were allocated to one of two training groups: cardiovascular (CT) (n = 6) or mixed (MT) (n = 7). Participants followed a given protocol for six weeks and aerobic capacity was assessed at week 0, 2, 4, and 6 by metabolic cart. Muscular strength was measured as bicep, triceps, and leg extension maximum-length holds, performed biweekly. Bodyweight and bodyfat was measured biweekly. CT subjects exhibited a significant decrease in aerobic capacity over the 6-week period compared to individuals in the MT group (-7.59±8.34% vs. 3.70±5.26%, respectively, $p=0.014$). Leg strength saw a significant increase in the CT group (120±40%, $p=0.002$) but not in the MT group (110±179%, $p>0.05$). Bodyweight change was insignificant in both groups, but bodyfat decreased significantly in the MT group (-14.6±11.5%, $p=0.01$) while remaining unchanged in CT participants (2.1±9.0%, $p>0.05$). Noncompliance to protocols was due to a lack of time in 70% of cases. Our findings indicate that thirty minutes of cardiovascular exercise performed three times per week may be insufficient to maintain fitness in students. Additional resistance training may be a useful strategy to attenuate physical decline and improve body composition. Insufficient time should be addressed as a significant barrier to exercise in students.

Introduction/Background Research:

Obesity poses one of the most significant public health threats in the 21st century and exists as a powerful predictor of life-threatening diseases such as diabetes, heart disease, coronary artery disease, and non-alcoholic fatty liver disease. In many cases, college students are especially vulnerable, given the abrupt increase in independence offered to students upon the transition from high school to university. This transition and the frequently observed concurrent increase in bodyweight are often referred to in popular culture as the “freshman fifteen”. Students, upon taking control of their own diet, living situation, and workout schedule, may quickly begin to consume increasingly unhealthy foods and see attenuated exercise levels as the demands of university life begin to accelerate. Additionally, many high school athletes do not participate in college sports, and thus find themselves unable to effectively design, manage, and follow through on a workout schedule of their own accord. In a study investigating obesity, diet, and physical activity in college students, 21.6% were found to be overweight by BMI (Huang et al 2003). Additionally, this study found that nearly 70% of students were not consuming the recommended daily five servings of fruits or vegetables per day, therefore neglecting key nutrients from their diets. Given that many individuals begin to develop lifelong habits during their college-age period, it is essential for students to nurture effective diet and exercise strategies in order to maximize their health moving forward. Furthermore, a lack of time as a barrier to exercise exists in college students and throughout the population, allowing any results to be extrapolated beyond the initial demographic. Thus, college students exist as a highly useful model for exercise and behavioral study.

Aerobic capacity, also known as VO2 max, is an important marker when considering overall health. Research has previously demonstrated that a low aerobic capacity places an individual at risk for cardiovascular disease to a higher degree than does a primarily sedentary lifestyle (Franklin 2007). In fact, discussion has been posed for the establishment of "physiological age," through VO2 max measurement as a more accurate gauge of physiological decline comparative to traditional chronological age because ones VO2 declines with age (Hollenberg et al. 2016). Aerobic capacity tests an individual's capability to utilize oxygen while performing at high intensity. Aerobic capacity may be determined through a number of techniques. Often, submaximal tests are utilized in order to glean cardiorespiratory fitness without the necessity of expensive equipment. Tests such as the Astrand nomogram, certain step-up tests, and timed one-mile walks may be used as an alternative to traditional gas output analysis. Maximal tests, on the other hand, are traditionally performed on a treadmill or stationary bike. Treadmill tests, in particular, tend to produce higher VO2 max values due to the fact that running involves a more systemic workout than does cycling, which isolates the legs (Borror 13).

Most commonly, and of preference in scientific research, aerobic capacity is measured through the use of a metabolic cart. A metabolic cart employs gas analysis in order to determine the cardiorespiratory fitness of an individual. The machine functions by measuring oxygen consumption and carbon dioxide production while exercise is performed at high intensity. In many cases, metabolic carts are employed while an individual performs a so-called "maximal test," which may last fifteen to thirty minutes and is considered. This test is exhaustive and is performed at the limits of an individual's capacity for physical output; In fact, some participants may faint or collapse following completion of the test. Because maximal tests are difficult, expensive, and sometimes dangerous, submaximal tests are often utilized as an alternative. However, submaximal tests are inherently less accurate than exhaustive tests, given the necessity for an extrapolation of results to predict maximal VO2. Simple best-fit lines are traditionally employed in order to perform the extrapolation from submaximal data points to an estimated VO2 max. In addition to heart rate, oxygen consumption and carbon dioxide production, the metabolic cart also measures "respiratory quotient" (RQ). This value indicates the type of fuel being utilized by the body during exercise by calculating the ratio of carbon dioxide produced to oxygen consumption. An RQ value of 1.0 indicates pure carbohydrate utilization during exercise, while an RQ of 0.7 indicates lipid oxidation as the primary fuel source. Between individuals, the ability to utilize a greater amount of lipids at an equivalent level of physical output indicates a greater level of fitness. Lipid oxidation requires significantly more oxygen than does glycogenolysis. Therefore, the ability to continue lipid oxidation throughout increasingly difficult degrees of exercise indicates an improved ability to oxygenate tissues without the need to switch to a fuel source with attenuated oxygen demands. As a whole, it is clear that the higher an individual's aerobic capacity, the higher their fitness level, given that such an individual is able to utilize oxygen more efficiently and at a greater level of physical output (Shete, et al 2014).

Increasing VO2 max can be accomplished through a number of strategies, and research has shown that both aerobic and anaerobic training can be used to increase VO2 max, but to different extents (Tabata et al 2006). As discussed, lipid utilization occurs when the body is functioning at a level of oxygen abundance. In other words, exercise performed within the bounds of fatty acid oxidation occurs at a purely aerobic level. Once exercise reaches a degree of intensity that oxygen becomes scarce, the less oxygen-dependent carbohydrate metabolism must commence in order to prioritize tissue oxygenation. Pure carbohydrate metabolism indicates that the body is functioning anaerobically, and that oxygen is insufficient to continue aerobic energy pathways. Training each of these energy systems may increase VO2 max, but the upsides and downsides of specifically performing anaerobic or aerobic exercise remains up for debate. However, it is generally agreed that targeting both systems provides for a well-rounded approach to physical fitness (Patel et al. 2017).

A lack of time presents a significant barrier to exercise in a number of populations, including university students (Van Niekirk et al. 2010) Academic schedules and extracurricular demands may hinder the ability of many students to exercise effectively and on a regular basis. While certain universities are implementing physical exercise-based courses in order to improve student body fitness, many schools of higher education are removing extracurricular activities and encouraging self-driven forms of recreation in lieu of organized programs, often for the sake of funding. Given the vulnerability of college students to weight gain and the associated negative outcomes, it is essential for universities to offer physical education classes. Furthermore, mandating participation on behalf of students in one or more of these activities in return for academic credit would yield a significant benefit to students by reducing time-strain and allowing improved accessibility to fitness.

Hypothesis:

We hypothesize that participants in the cardiovascular exercise only group will show greater improvement in aerobic capacity but not in strength compared to the mixed (cardiovascular and resistance) group, while the mixed training group will exhibit a greater increase in strength compared to the cardiovascular group.

Methods:

Participants were recruited through word of mouth via visits to classrooms at the University of Portland and through email inquiries, and all participants were students between the age of 18 and 22. Prior to beginning the study, each participant completed a survey to ascertain the amount and type of exercise they traditionally performed prior to beginning the study. Participants were then randomly assigned to one of two training groups: cardiovascular (CT) (n = 6) or mixed training (MT) (n = 7). There were ten female participants and three male participants. CT subjects were instructed to perform cardiovascular exercise for 30 minutes, three times per week, for six weeks. They were given limited modalities of exercise they could perform including running, swimming, rowing, and climbing stairs. These subjects were specifically instructed not to engage in cardiovascular exercise with predominantly resistance-based aspects, such as high-intensity interval training with dumbbells. MT subjects were instructed to perform 15 minutes of a resistance training with 15 minutes of cardiovascular training at an equivalent frequency. These participants were also given limited modalities and instructed to perform these two types of exercise exclusively. The resistance group was instructed to follow a protocol consisting of two days of upper body (“push” and “pull” days) and one day of leg exercises in order to ensure that all areas of the body were stimulated with some degree of equivalency.

Exercise intensity was standardized by heart rate in order to ensure equality of effort between experimental groups. Participants were given heart rate monitors (Polar H10) with Bluetooth capabilities in order to allow heart rate tracking throughout the workout using a mobile device. Subjects were instructed to maintain their heart rate between 60 – 80% of maximum. Given the similarity in ages of the participants, this was between 120 and 180 beats per minute (bpm).

Additionally, participants were given weekly surveys in order to measure their compliance with the given exercise protocols.

Lab testing was performed at the outset of the project, prior to the implementation of exercise protocols, and biweekly thereafter. Aerobic capacity, strength, body weight, and body fat were assessed at week 0, 2, 4, and 6 by metabolic cart, maximum length dumbbell holds, simple scale, and electrical impedance, respectively. Height was measured once and assumed consistent throughout. Weight was measured with a simple step-on scale. Body fat percentage was measured using a handheld electrical impedance device. Biceps, triceps, and leg (namely, quadricep) strength was tested using a timed maximum dumbbell hold. For biceps, individuals held the dumbbells in front of them with a ninety-degree angle at the elbow. Triceps were assessed through performance of a maximum-length overhead hold, also using an initial ninety-degree elbow bend. Leg strength was tested through a leg-extension hold, wherein participants were seated with a dumbbell affixed to their ankle and instructed to maintain full extension until muscular failure.

Aerobic capacity was measured via the metabolic cart and a treadmill test. Participants ran at three different speeds, which remained consistent throughout the entirety of the protocol. Once participant heart rate reached equilibrium at any given speed, the speed was increased. This was repeated until heart rate stabilized at the third and final speed. Prior to each speed increase, participants indicated their level of exertion based on the Borg Scale of Perceived Exertion. If a value of 19 or 20 were indicated, the test would be stopped to ensure safety. When the data collection period was completed, the maximum volume of oxygen consumption (VO2 max) was determined via extrapolation of the three data points, as shown in Figure 1. Changes in each of the variables collected was measured for each individual and then the groups as a whole before being compared.

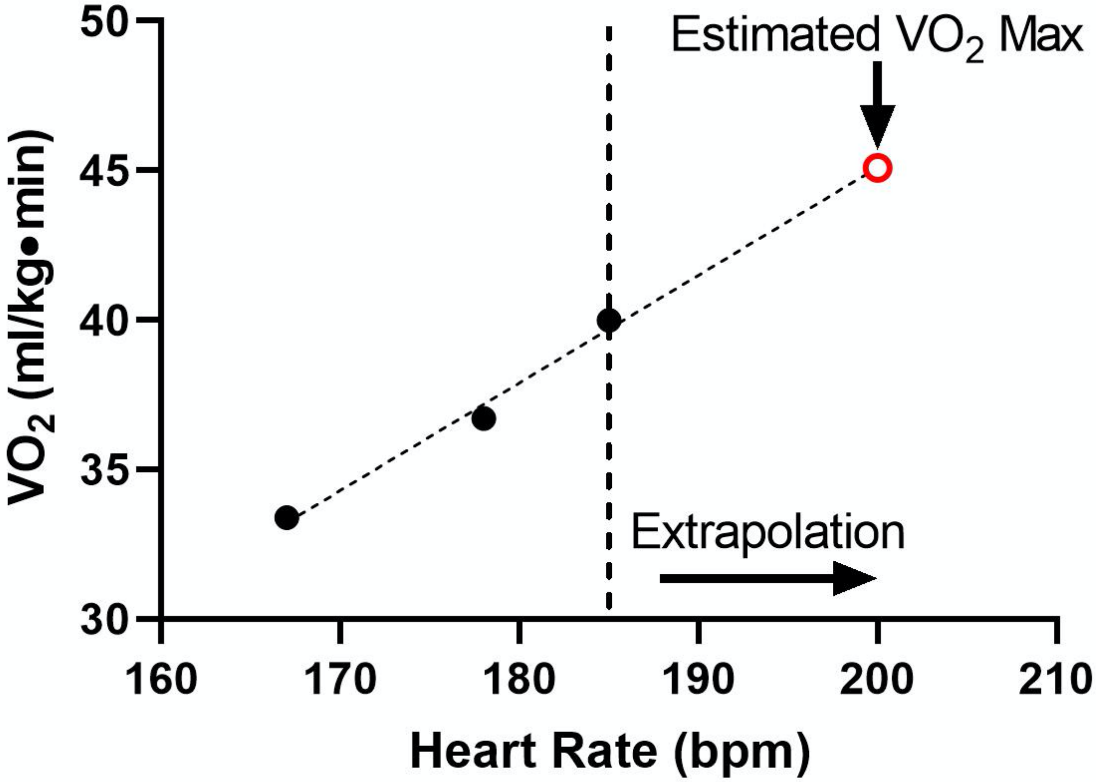

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Figure 1. Typical submaximal VO_2 assessment and maximal estimation. Oxygen consumption values obtained through heart rate stabilization points during three-stage treadmill run of increasing speed.

Throughout the study, individual data was kept anonymous via a codified system and data access was limited to the two researchers and faculty advisor.

Results:

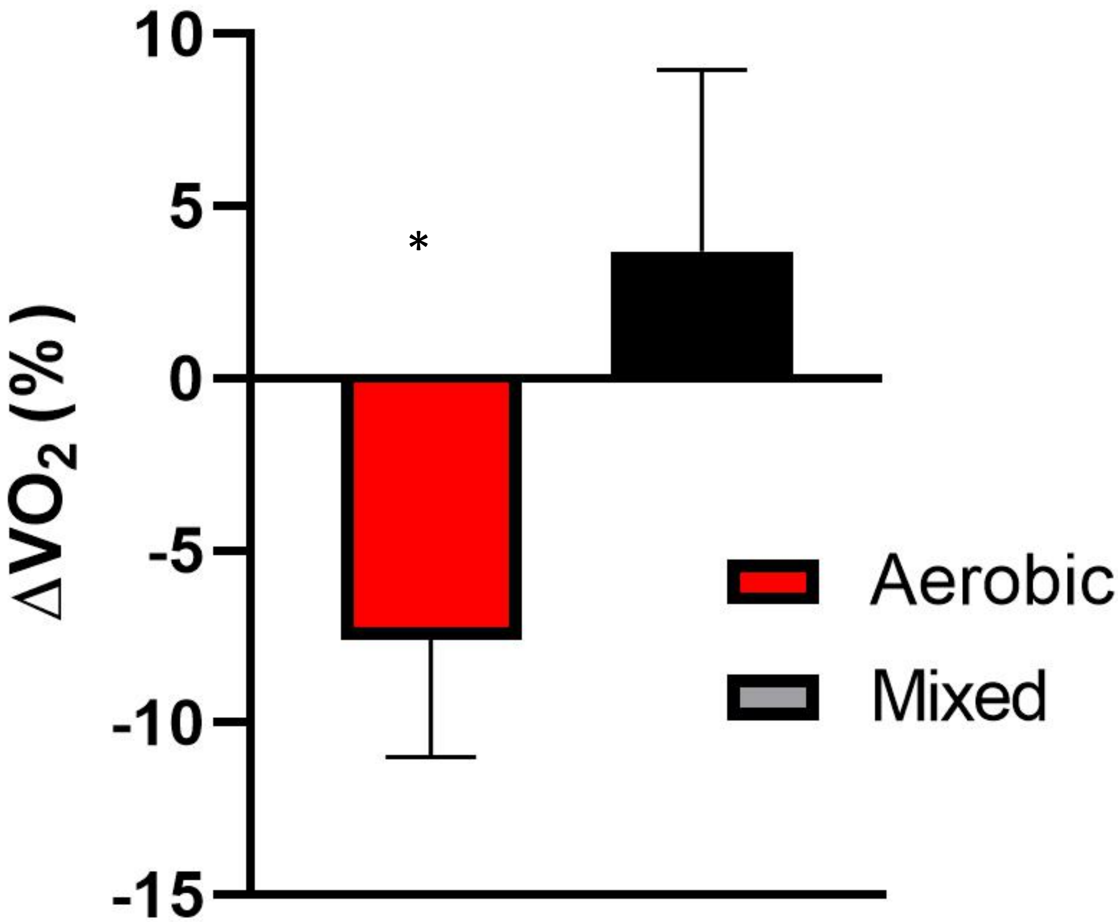

Figure 2. Subject aerobic capacity change over 6-week training period. CT group subjects exhibited a significant decrease in aerobic capacity over the period compared to individuals in the MT group (-8.78±7.09%, $p=0.03$ vs. 3.70±5.26%, $p>0.05$, respectively). Asterisk denotes significant difference from baseline. VO2 was measured in mL of oxygen per minute per kilogram of body weight.

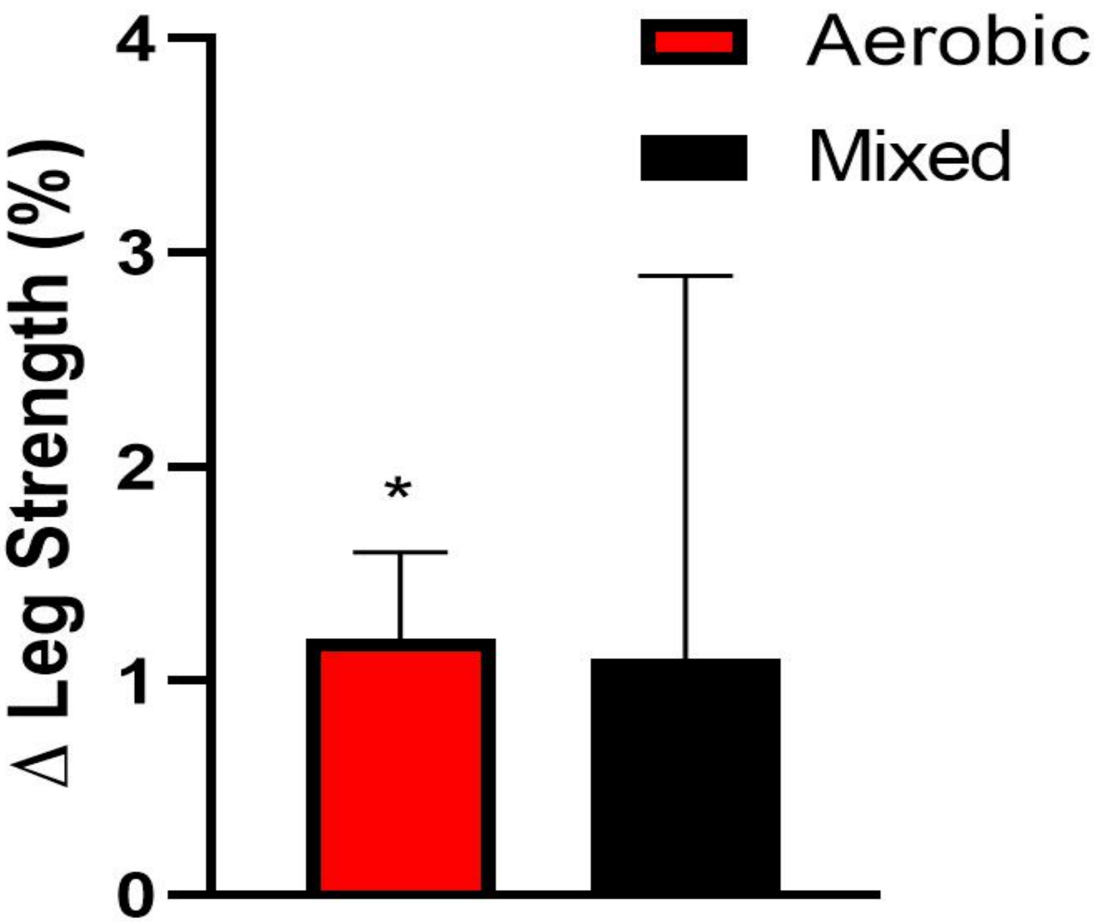

Figure 3. Subject leg strength change over the 6-week training period. Leg strength saw a significant increase in the CT group (120±40%, p=0.002) but not in the MT (110±179%, p>0.05). Asterisk denotes significant difference from baseline. Change in leg strength was measured in seconds.

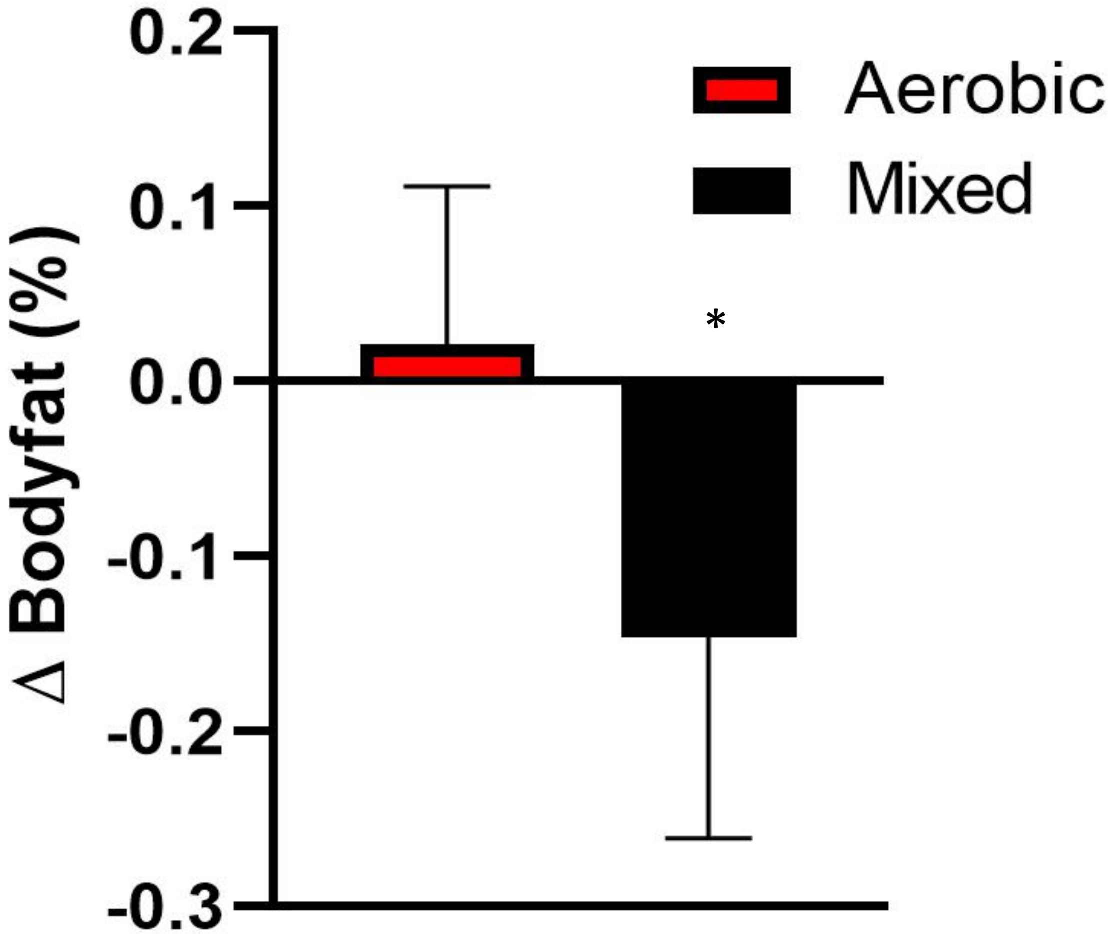

Figure 4. Subject body fat change over the 6-week training period. Body weight change was insignificant in both groups (3.42±8.68lbs and -2.4±3.42lbs, respectively, p>0.05), but body fat decreased significantly in the MT group (-14.6±11.5%, p=0.01) while remaining unchanged in CT participants (2.1±9.0%, p>0.05). Asterisk denotes significant difference from baseline. The y-axis should be listed as full percentage change.

Discussion:

Given the obtained data, our proposed hypothesis was not supported. Initially, it was hypothesized that the CT group would exhibit an increase in aerobic capacity whilst the MT group would showcase a more notable increase in strength. However, the CT group displayed a significant decrease in aerobic capacity whilst the MT group remained unchanged in regard to estimated VO2 max (-8.78±7.09%, $p=0.03$ vs. 3.70±5.26%, $p>0.05$, respectively). A number of factors may have contributed to these results. Namely, the high degree of pretraining exhibited by the cohort utilized in this project may have created a circumstance wherein the administered protocols represented a decrease in activity from baseline among subjects. Thus, compliance to the protocols over the course of the six-week project could have allowed fitness levels to drop.

Regarding muscular strength, neither group experienced significant changes in upper-body strength, but CT participants exhibited a significant increase in leg strength over the course of the project (120±40%, $p=0.002$), whereas MT participants did not (110±179%, $p>0.05$). It is counterintuitive that the participants performing primarily cardiovascular exercise exhibited an increase in leg strength, whereas the participants permitted to directly train legs did not. However, a number of factors may have contributed to this result, particularly given the magnitude of the demonstrated increase. In particular, participant familiarity with the testing protocols employed in order to asses leg strength may have contributed to the observed increase. Standardizing the test also presented some degree of difficulty, given the orientation of the bench upon which participants were seated and the manner in which the dumbbell was affixed to the ankle.

Bodyweight did not see a significant change over the course of the project in either group (3.42±8.68lbs and -2.4±3.42lbs, respectively, $p>0.05$). However, bodyfat decreased by a significant degree in the mixed group (-14.6±11.5%, $p=0.01$). This result may be the direct effect of the implemented protocols. Nonetheless, this project did not control the diet of subjects and thus a change in bodyfat may also the result of a sustained caloric deficit on part of the participant.

In the weekly surveys, students who were unable to perform the 90 minutes of weekly exercise following the protocol indicated that 60% of this was due to a lack of time in their schedule. This suggests that time is an especially important factor when trying to manage exercise at the college age, and time management skills should be addressed in conjunction with implementing exercise regimens. Given time being such an important factor, we suggest that this university implement credit-based exercise classes. This would encourage students to fit in exercise and maintain habits that are health promoting.

We acknowledge that there are aspects of the study that could be improved upon, most notably controlling a number of confounding variables that could affect the results of the data. Given this, a number of recommendations might be made for the provision of improved data fidelity upon the recreation of this project in the future.

Twelve of the thirteen participants were performing exercise at a greater frequency than what was required of them during the study. This decrease in exercise may have contributed to why there was a significant decrease in the aerobic capacity in the cardiovascular group. In the future, a study could be performed that exclusively changes the type of exercise that participants perform without changing frequency in order to limit the number of changing variables. Additionally, this suggests that ninety minutes per week may not be sufficient to maintain aerobic capacity in previously highly trained individuals. Given the general increasing trend in aerobic capacity for the mixed group, it is possible that resistance training could help to attenuate this decline. However, without significant results it is difficult to conclude this with certainty.

We believe that increasing the number of participants would help better control for outliers. At the outset of the study, there were thirty-one participants. Unfortunately, many dropped out after being assigned an exercise group and several weeks of testing. Thus, there were a total of thirteen participants who completed the study. In the future, retention rate could be increased by alerting participants to the full expectations at outset of the study, as many did not wish to change their current exercise routine to match the rigors of the protocol.

A certain degree of mathematical error may be present when performing a submaximal test and extrapolating data. While an exhaustive VO2 maximum test would yield more accurate results, it can be dangerous without the necessary precautions, and therefore this was not performed during this study. There are also inherent difficulties when performing a VO2 test as the participant is not working out in their space of comfort but instead is in a laboratory setting and wearing a mask that could make breathing naturally more difficult. Some participants also missed a week of the treadmill test due to illness, and thus final VO2 data had to be predicted from three data points instead of four. Due to the demands of college schedules, some participants were not able to come in consistently 14 days apart. Instead, certain participants may have undergone testing at a frequency of slightly more or slightly less than 14 days, which may have skewed the results in regard to inter-participant comparison. Testing was also performed at different times of day due to both the student and researcher schedules, which could also yield varying results and should be controlled for in the future.

Throughout the study, there was no control for a variety of lifestyle factors. Chiefly, diet plays a significant role in regard to the body fat percentage of an individual, and the lack of dietary restrictions in this project may present an explanation for the observed changes. As previously discussed, a sustained caloric deficit or surplus by any individual could exert a dramatic effect on body fat percentage and body weight change. A significant decrease in body fat percentage in the mixed group was not expected, particularly due to the fact that each individual group was intended to exercise with equal intensities. Controlling for diet and other variables, including sleep, could help to reduce the number of confounding variables with the potential to affect bodyfat percentage change. It is also possible that the loss in body fat percentage in the mixed group was due to an increase in amount of lean muscle, changing the proportion of lean muscle to body fat. Extraneous physical activity was also not controlled in the study, and individuals may have engaged in sporadic indirect exercise outside the scope of the exercise protocols. Further restrictions on the behavior of participants would allow for a more accurate analysis of the relationship between the administered exercise and the observed results.

Conclusion:

Our findings indicate that thirty minutes of cardiovascular exercise performed three times per week may be insufficient to maintain fitness in college-aged students, especially those who were performing more than that at baseline. Our hypothesis was not supported as we saw a decrease in aerobic capacity and increase in strength in the cardiovascular training group. Additional resistance training may be a useful strategy to attenuate physical decline and improve body composition. Insufficient time should be addressed as a significant barrier to exercise in students and exercise classes for credit may be a strategy by which to improve accessibility.

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