Postoperative Body Composition in NCAA Division I Collegiate Athletes

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INTRODUCTION: Determining return to sport for athletes after surgery can be challenging**.** Some evidence suggests the risk for injury changes with differences in anthropometrics. Therefore, body composition may be predictive of risk for reinjury after orthopaedic surgery in Division I athletes. The purpose of this study is to establish an objective model of anthropometric changes of Division I collegiate athletes following orthopaedic surgery with specific consideration of gender differences for potential use in future nutritional and return-to-play guidelines.
METHODS: Division I athletes who underwent orthopaedic surgery in a five-year window were identified using training room records and cross-referenced against the facility BOD POD (air displacement plethysmography) database for body metrics. Changes in body metrics were evaluated as trends from the immediate preoperative measurement up to 1 year following the date of surgery. Data was analyzed with respect to gender and sport. Significance was determined as $p<0.05$.
RESULTS: In total, 245 Division I athletes were identified as having undergone orthopaedic surgery in the study period. Eighty-four athletes representing 11 sports met the inclusion criteria. Overall, athletes were found to experience a 0.89kg reduction in fat-free body mass ($p = 0.021$) and an increase in body fat percentage by 1.15% ($p = 0.002$) from baseline measurements over the 5-month period following surgery at an average rate of -0.18kg and +0.23% body fat per month, respectively. At the conclusion of the 12-month period following surgery, measurements of fat-free body mass ($p = 0.341$) and body fat percentage ($p = 0.104$) were not found to differ significantly from preoperative baseline. The greatest decrease in fat-free body mass ($p = 0.013$) and increase in body fat percentage ($p < 0.001$) of male athletes was found the first 3 months after surgery before trending towards baseline months 4-12. The greatest increase in body fat percentage for female athletes was found the first 4 months after surgery before trending towards baseline months 5-12 ($p = 0.049$). No significant trend was observed in fat-free body mass of female athletes ($p = 0.420$).
CONCLUSION: This study demonstrates that NCAA Division I collegiate athletes undergo statistically significant anthropometric changes following sports-related orthopaedic surgery, with distinct differences observed between male and female athletes. These changes return to a level that does not significantly differ from baseline body composition measurements one year following surgery. We hope to motivate further studies to compare these trends against return-to-play time and reinjury rates of athletes to provide validated novel metrics for consideration in guiding athlete recovery following surgery.

INTRODUCTION

The transition from elite level competition and training to forced activity modification and immobilization following injury and surgery can result in abrupt changes to muscle loading, metabolic demand, and nutrient utilization. While there is a historically and colloquially well-known period of deconditioning following such events, the specific changes to anthropometric values of body

DOI: 10.53646/30khc538
Published online: December 17, 2023

composition in this setting have not been strictly characterized.[1-2]

In the case of decreased lean body mass, and presumably muscle volume, the resultant decrease in strength lessens the stabilizing and dampening capacity of muscle, thereby increasing the forces distributed to associated structures and increasing risk for injury.[3-6] Similarly, the association with higher risk for orthopaedic injury in athletes with increased body fat percentage and increased BMI has been previously documented, though the mechanism by which body fat may predispose an athlete to injury is much less clear.[7-10] Based on the overall reported evidence of an athlete's increased risk for injury with differences in body composition, it is the authors' belief that changes in body composition following surgery may be indicative of risk for reinjury following surgery.[1,7-9] This presents a unique target for individualized assessment of readiness for return-to-sport (RTS).

Historically, RTS guidelines for athletes following a surgical procedure were primarily determined on a timeline basis, where the athlete is permitted to return to activity in a progressive, stepwise model of increased activity at predefined temporal milestones.[11-12] Recently, accelerated recovery programs have permitted athletes to return to activity in less time using individualized, goal-based models that allow an athlete to progress through a similar stepwise model after achieving certain levels of functional activity.[13-17] While this has helped athletes return to sport in a reduced time without significantly increased rates of complication, the metrics used in these models, such as pain, swelling, strength, and mobility are all inherently difficult to standardize, leading to variable implementation of return-to-sport protocols.[13-17]

There exists a paucity for standardized measurements that can be used to guide an athlete's return to play in an accelerated fashion on an individualized basis while minimizing risk and maximizing recovery.[18-19] Furthermore, while anthropometric models of athlete recovery may be of prognostic value, the authors hypothesize that the physiologic response to injury and abrupt changes of physical activity will differ amongst men and women athletes, and thus require distinct, independent analysis and modeling.

The purpose of this study is to describe and establish objective models of anthropometric changes of NCAA Division I collegiate athletes following surgery to be compared against return to play times and reinjury rates for the potential use in future nutritional and return-to-play guidelines of athletes following orthopaedic sports medicine procedures.

METHODS

Obtaining Patient Data

NCAA Division I athletes from a United States public university who had undergone orthopaedic sports medicine surgical procedures over a five-year study period were retrospectively identified using deidentified training room records and cross-referenced against the facility BOD POD (air displacement plethysmography, COSMED, Rome) database for athlete's sport, gender as defined by collegiate men's and women's sport divisions, and body metrics. The data from training room records and BOD POD information is stored and maintained by the collegiate varsity training facility staff and had been accessed and deidentified before providing the data set to the researchers involved in this study. Because all identifying information had been removed from the data before being provided to the authors, our institution concluded that the study does not fall under the jurisdiction of the Institutional Review Board (IRB) and is subject to the constraints of the Family Educational Rights and Privacy Act (FERPA).

For each athlete, data points were collected at up to two measurements immediately prior to date of surgery and up to six measurements immediately following surgery, if available. Each measurement consisted of sport, gender, number of days prior to or following date of surgery, body mass, fat-free mass, fat mass, percent fat-free mass, and percent fat mass. Only athletes meeting inclusion criteria were included in data analysis, which consisted of the following: 1) varsity collegiate athlete at the university affiliated with this research team, 2) having experienced a sports medicine related orthopaedic injury, 3) requiring surgical intervention while still enrolled in the institution and 4) remaining a member of the respective athletic team throughout injury and recovery. Patients were excluded from analysis if they did not meet both of the following requirements: 1) one or more preoperative baseline BOD POD measurement within 90 days before date of surgery and 2) one or more one postoperative BOD POD measurement within 365 days after surgery.

DOI: 10.53646/30khc538
Published online: December 17, 2023

Statistics

Each athlete was analyzed as an independent model with trends over time using the data points from preoperative and postoperative values for each of the studied variables and adjusted with respect to gender and sport using a mixed effect model with random intercept and CS variance-covariance to assess trends over time. Piecewise models were used to determine significant points of inflection in the observed trends. Data were reported with respect to time in one-month intervals. Significance was determined as p <0.05.

RESULTS

From training room records, 245 NCAA Division I athletes were identified as having undergone an orthopaedic surgical procedure in the past 5 years. Of them, 84 athletes met inclusion criteria, consisting of 57.1% female and 42.9% male athletes (Table 1). These athletes represented 11 sports, including football: 27.4%, gymnastics: 19.0%, soccer: 13.1%, softball: 10.7%, volleyball: 10.7%, basketball: 7.1%, baseball: 2.4%, rowing: 2.4%, swimming: 2.4%, tennis: 2.4%, and water polo: 2.4% (Table 1)

Table 1. Athlete Demographics *(n=84)*

Variables		***Athletes, n (%)***
Gender	Male	36 (42.9)
	Female	48 (57.1)
Sport	Football	23 (27.4)
	Gymnastics	16 (19.0)
	Soccer	11 (13.1)
	Softball	9 (10.7)
	Volleyball	9 (10.7)
	Basketball	6 (7.1)
	Baseball	2 (2.4)
	Rowing	2 (2.4)
	Swimming	2 (2.4)
	Tennis	2 (2.4)
	Water Polo	2 (2.4)

Overall, athletes' body composition was measured at an average of 4.6 interval periods (range 2-8) throughout recovery and were found to experience a 0.89 kg reduction in fat-free body mass (p = 0.021) and a 1.15% increase body fat percentage (p = 0.002) from baseline measurements over the 5-month period following surgery at an average rate of -0.18kg and +0.23% body fat per month, respectively. At the conclusion of the 12-month period following surgery, measurements of fat-free body mass (p = 0.341) and body fat percentage (p = 0.104) were not found to differ significantly from preoperative baseline.

Further analysis by gender revealed that male athletes demonstrated the greatest reduction in fat-free mass at a rate of -0.33kg each month from months 1-3 following surgery (Figure 1, p = 0.044) before a significant inflection is observed between postoperative months 3 and 4 (Figure 1, p = 0.013). Following this inflection, male athletes demonstrated an increase in fat-free body mass at a rate of +0.20kg per month from months 4-12 following surgery (Figure 1, p = 0.006). Female athletes demonstrated a decrease in fat-free body mass during postoperative months 1-3 before experiencing an increase in fat-free body mass during postoperative months 4-12, but this was not found to be statistically significant (Figure 1, p = 0.420).

Both male and female athletes were found to undergo significant increases in body fat percentage before reaching a point of inflection and returning to baseline levels.

DOI: 10.53646/30KHC538
PUBLISHED ONLINE: DECEMBER 17, 2023

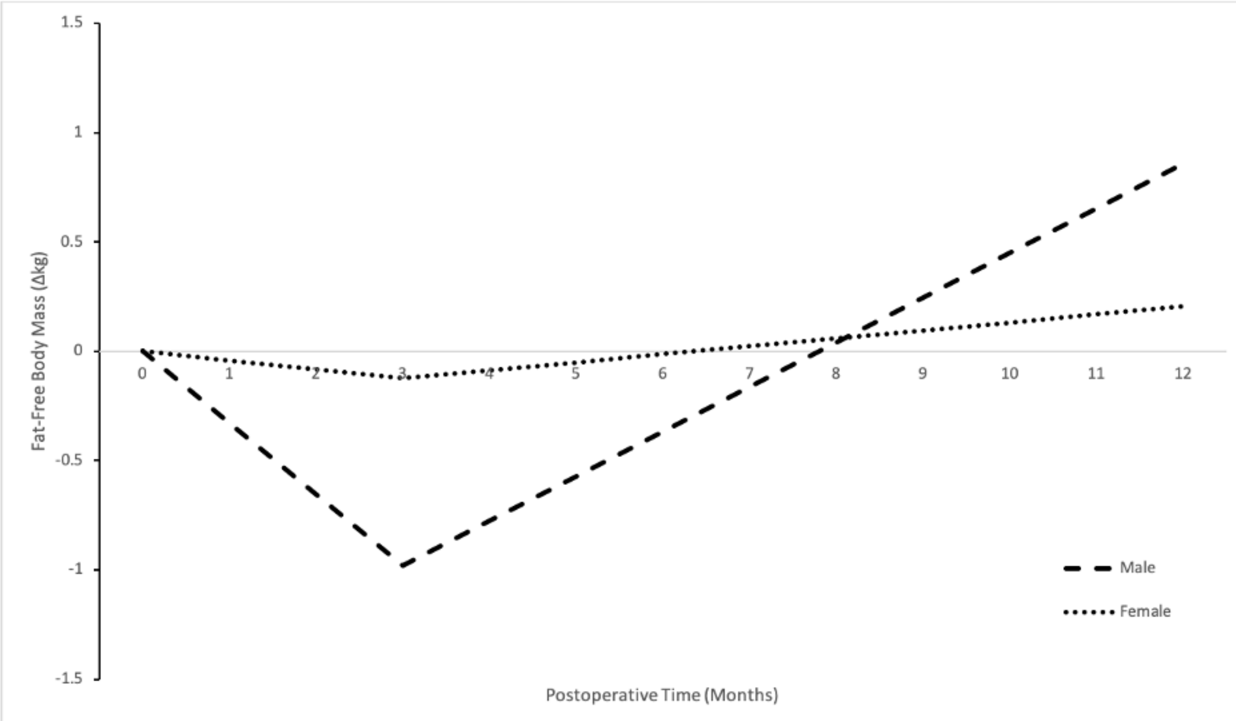

Figure 1. Mean change in collegiate athlete fat-free mass following orthopaedic surgery by gender. Depicted is average change from preoperative baseline fat-free body mass up to one year following surgery.

In male athletes, the greatest increase in body fat percentage took place from postoperative months 1-3 at a rate of +0.50% per month (Figure 2, p = 0.0008) before reaching a significant point of inflection between postoperative months 3 and 4 (Figure 2, p = 0.017). Following this inflection, male athletes demonstrated a decrease in body fat percentage at a rate of -0.16% per month from months 4-12 following surgery (Figure 2, p <0.001). Female athletes experienced an increase in body fat percentage at a rate of +0.21% per month from postoperative months 1-4 (Figure 2, p = 0.049) before demonstrating the greatest point of inflection between postoperative months 4 and 5 (Figure 2, p = 0.035). Female athletes then demonstrated a decrease in body fat percentage at a rate of -0.10% per month from postoperative months 5-12, though this relationship did not reach statistical significance (Figure 2, p = 0.092).

DISCUSSION

The model established by the results of this study highlight several characteristic features that may serve as potential clinical targets for alterations in the management of postsurgical athletes. First, nearly all athletes were able to return to a level of lean body mass and body fat percentage that did not differ significantly from baseline within one year, many of which were able to surpass baseline levels of lean body mass. This suggests that anthropometric changes resulting from surgery are reversible, and complications outside of one year are unlikely to be related to changes in body composition. Second, it is notable that the decompensatory anthropometric changes observed in the first three to four months following surgery occurred at a significantly greater rate than the rate of recovery towards baseline over the subsequent eight to nine months. By preventatively limiting these rapid changes in the first three to four months via modified diet and exercise regimens, the time at which an athlete returns to his or her baseline may be substantially decreased. Lastly, this study demonstrates there are significant differences observed between the postoperative anthropometric changes that occur in male and female athletes, warranting independent consideration when monitoring and guiding the athlete's recovery. It is important to note that while this study demonstrates statistical significance, the clinical significance of these changes has not yet been determined.

DOI: 10.53646/30KHC538
PUBLISHED ONLINE: DECEMBER 17, 2023
2769-4895 © JOURNAL OF WOMEN'S SPORTS MEDICINE

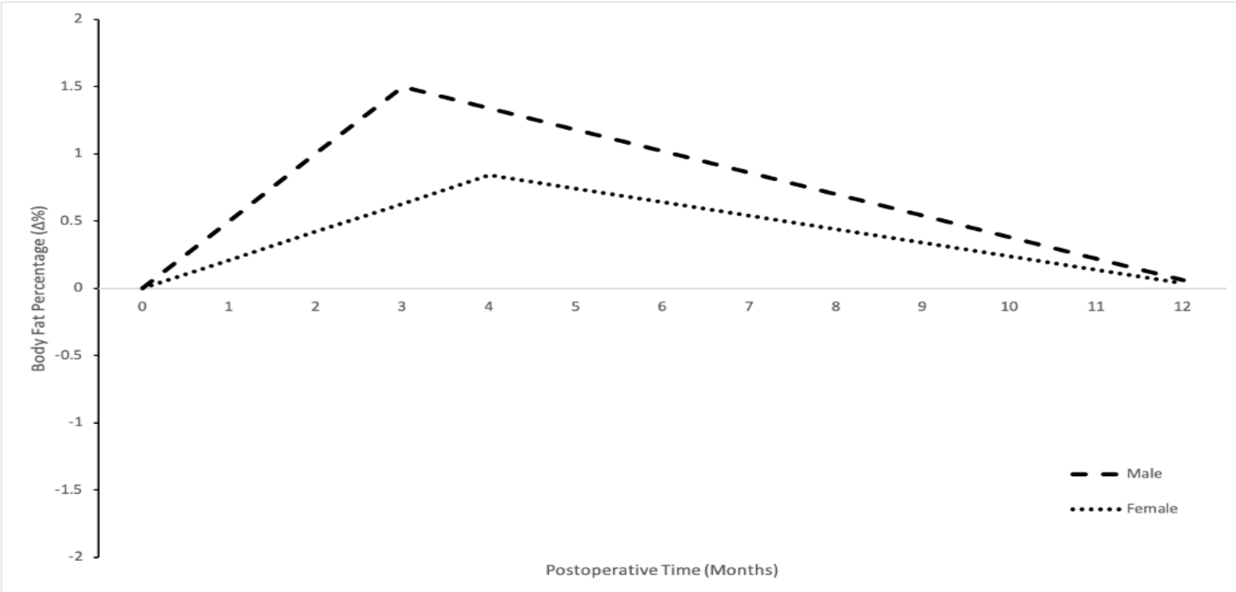

Figure 2. Mean change in collegiate athlete body fat percentage following orthopaedic surgery by gender. Depicted is average change from preoperative baseline body fat percentage up to one year following surgery.

Few studies have looked at compositional changes in athletes after orthopaedic surgery, though studies of quadriceps muscle volume following ACL reconstruction demonstrate a loss of muscle size compared to preoperative values.[20-21] This change in muscle volume may provide one explanation for the observed difference in lean body mass demonstrated in our study. There is variable statistical significance of these changes noted in the meta-analysis by Birchmeier et al., though it should be noted that the time points for comparison to preoperative values studied ranged from seven months to three years.[20] Given our findings of recovery to baseline preoperative lean body mass within the first year, it is likely that these studies may be evaluating the tail end of physiologic differences, or may have been too late entirely to visualize any difference prior to recovery. A use-dependent de-loading of skeletal muscle is well characterized to result in a rapid, profound, and importantly reversible atrophy.[22-27] In the context of orthopaedic surgery following a sports-related injury, this forced de-loading may explain a large component of the loss of skeletal muscle volume and therefore lean body mass of the affected limb. Additionally, the expected discontinuation of athletic participation following surgery may also contribute to a more generalized de-loading and loss of skeletal muscle volume as a consequence of a decrease in the high levels of load-bearing exercise and resistance training typically performed by the collegiate athlete.

Interestingly, the increase in body fat percentage observed of athletes following surgery cannot be completely explained by a parallel decrease in lean body mass, as evidenced particularly by the changes in female athletes observed in our study, who did not demonstrate a significant reduction in lean body mass, and yet increased body fat percentage significantly over four months following surgery. One possible explanation for these changes may be an abrupt cessation of athletic participation, and therefore a significant decrease in daily metabolic expenditure of the athlete while continuing baseline dietary regimens.[28-29] A similar relationship of retained lean body mass but increased body fat percentage is observed in a study of acute detraining at the end of competitive season for collegiate level swimmers.[30] Reviews by Carlsohn et al. and Hills et al. discuss the important relationship between physical activity levels and energy expenditure, leading to overall changes in nutrition requirement based on activity. It can be hypothesized that during the forced detraining period following injury and subsequent surgery, excess nutrition and a possible predisposition to disordered eating in the athlete population noted by Tanaka et al. may lead to increases in stored body fat as is demonstrated in our study.[28-31] The changes observed in this study, however, return to baseline within one year, likely

DOI: 10.53646/30khc538
Published online: December 17, 2023

correlating with return to sport and increased energy expenditure.

Given the associations of differences in body composition affecting athletic performance and predisposing an athlete to injury seen in the literature, it is reasonable to consider the decompensatory anthropometric changes of an athlete following surgery when calculating risk of reinjury to the affected site, or secondary injury to a separate anatomical site.[7-10, 32-34] Assessing the body composition of a recovering athlete may therefore provide valuable insight in determining the athlete's preparedness for return to play. While the findings of this study are consistent with the expected use-dependent atrophy and decreased metabolic demand of the participation-restricted athlete, no studies to the author's knowledge have quantified the observed changes or established a model of the body composition of athletes following surgery, particularly considering gendered differences between male and female athletes. Ultimately, our aim is to identify new metrics for individualized RTS protocols. Given our results, we are optimistic that patterns of anthropometric response can be predictably modeled in the athlete population after surgery, though the clinical significance and link to reinjury cannot be determined with this data alone.

Limitations

Given that this study is a retrospective review out of a single institution, we did not have a large number of patients meeting inclusion criteria. Additionally, pre-surgical body composition values may not reflect a true baseline if surgery had been delayed for greater than the 90-day preoperative window used for our inclusion criteria. We were unable to track individual caloric intake in this retrospective study, though this limitation was accepted as the standardized nutrition counseling and recommendations from the performance nutrition department for all athletes served as an internal control for nutritional status. Athletes were unable to be characterized based on anatomic region, type of injury, type of surgery, individual sport, actual return to play time, and re-injury rates due to limitations on the information available under the constraints of FERPA, which we plan to incorporate in future iterations of this study. The authors recognize the value in these variables, and acknowledge the need for future studies to address these limitations for better characterization of body composition and postoperative considerations among athletes following sport-related orthopaedic surgery.

CONCLUSIONS

This study demonstrates that NCAA Division I collegiate athletes undergo statistically significant anthropometric changes following sports-related orthopaedic surgery, with a decrease in fat-free body mass and an increase in body fat percentage up to 5 months after surgery. These changes return to a level that does not significantly differ from baseline body composition measurements one year following surgery. Significant differences are observed between male and female athletes. We hope to motivate further studies to compare these trends against return-to-play time and reinjury rates of athletes to provide validated novel metrics for consideration in guiding athlete recovery following surgery.

Conflicts of Interest

The authors declare no conflicts of interest with the contents of this study.

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DOI: 10.53646/30khc538
Published online: December 17, 2023

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DOI: 10.53646/30khc538
PUBLISHED ONLINE: DECEMBER 17, 2023