Original Research Paper

The effect of fat distribution and nutritional behavior on balance and equilibrium of acrobatics and tumbling athletes

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Abstract: Acrobatics and Tumbling (A&T) is an emerging sport in the United States; balance and equilibrium are critical components of performance in this sport. Therefore, the aim of this study was to identify if body composition, fat distribution, and nutritional behavior affect the balance and vertical jump of A&T athletes.
Body mass index (BMI), whole body percentage of fat and skeletal muscle, and fat distribution of top and base A&T athletes from Fairmont State University were assessed using an impedance device (In Body 570). Nutritional behavior was assessed by a 3-day food log. Balance was measured by the time of holding a handstand in seconds. BMI, whole body, and truncal fat percentage were higher in base athletes when compared to tops ($p<0.05$). When associating balance with the variables, skeletal muscle mass was positively associated with balance ($r=0.49$, $p<0.05$), and the percentage of fat and fat accumulation in the lower limbs were negatively associated ($r=-0.47$ and -0.48, respectively $p<0.05$). When the association was tested within the position, the percentage of skeletal muscle mass and fat was only associated with balance in top athletes. Thus, training strategies to increment skeletal muscle mass and decrease body fat should be the focus to improve the balance of top A&T athletes.

Keywords: Performance; Acrobatics and Tumbling; Nutrition; Fat Distribution.

Introduction

Acrobatics and Tumbling (A&T) is an emerging sport in the United States performed by female athletes. A&T involves a skill set obtained by a combination of different sports such as gymnastics, trampoline, cheerleading and acrobatics. Because A&T favors body control in various positions both on the ground and in the air, both strength and flexibility are required. A&T athletes are divided into two positions, base athletes that display strength and balance, and top athletes that exhibit flexibility and agility.

Static balance, a critical component necessary for the quality execution of numerous tasks in A&T, is required for either top or base positions. According to Gómez-Landero et.al, (2021), it is common for acrobatic tops to adapt to holding inverted positions more frequently than bases (Gómez-Landero et al 2021). Omorczyk and colleagues (2018) analyzed the relationship between stability in two different positions (handstand and standing) in athletes practicing gymnastics and found that seniors have better control over the displacement of the center of feet pressure than juniors (Omorczyk et al 2021). Despite the amount of research on this topic; there is still debate on which strategies best improve balance in different sports.

Since tumbling is an essential component of A&T, athletes must develop mechanics for initiating acrobatic jumps. In rhythmic gymnastics, explosive strength of the leg extensor muscles plays a crucial role in the jumping performance (Kums et al 2005). In A&T, it is unknown if body composition and fat distribution affect jumping performance.

A&T athletes typically have competitive experience in various disciplines of gymnastics. Although the primary discipline is artistic acrobatics, others include trampoline, power tumbling and competitive cheerleading. Gymnastics has been determined to have the best balance ability and stance compared to other athletic sports teams. Characteristics and stereotype of an elite gymnast is distinguished by petite size, low body and fat mass, and late maturity (Hrysomallis C., 2011). Compared to gymnastics, A&T contains different elements that require strength, therefore A&T athletes might present a distinct body composition when compared to gymnastics.

Several studies have shown that body composition of athletes in various sports influences their level of performance (Thorland et al., 1981; Vitale & Getzin 2019). It is evident that nutritional behavior associated with training can be an important factor in body composition and to improve performance (Nascimento et al., 2016; Skinner et al 2020). Therefore, the aim of this study was to identify if body composition, fat distribution, and nutritional behavior are associated with the static balance and vertical jump of elite athletes of A&T.

Materials and Methods

Subjects

Twenty-six trained female athletes, ranging from ages 17-23, were selected from Fairmont State's Acrobatics and tumbling team. Data were collected between February and April 2022. All subjects had a minimum of two-year's experience in gymnastics and/or cheerleading. Participants were divided into two groups according to their role (base or top acrobatic athlete). All participants were free of any musculoskeletal injury within the previous six months, which may restrain participants from performing balance test skills. Before any participants were selected for testing or any data was collected, this study was submitted to the Institutional Review Board (IRB). Once approval was obtained from the IRB, informed consent were obtained from all participants taking part in this study.

Procedures

First, athletes performed static position on two handstands (inverted) in a single setting to determine the center of pressure measurement. The static tests participants performed each test twice, recording their last time. Participants had a maximum limit of three minutes for time holding a handstand test if expectations were exceeded with proper technique. During test performances, the examiner stood beside the athlete for protection purposes. After at least 48 hours of interval, athletes performed a vertical jump test using a Tandem Vertical Challenger. Participants were asked to not take any performance enhancing supplements three hours prior to testing.

Body Composition and Fat Distribution Assessment

InBody 570 Body Composition Analyzer (InBody, Inc.) was used to analyze body fat and body composition according to the manufactures' instructions. The device uses advanced methods of bioimpedance to assess skeletal muscle and fat mass, along with segmental fat distribution such as the trunk, left and right legs and arms. For legs and arms the average in weight was calculated and used for statistical purpose. Metabolic rate and skeletal muscle index (SMI- calculated by dividing appendicular lean mass by height in squared) was also quantified using the InBody 570.

Nutritional Behavior

Each A&T subject completed a 3-day food log to calculate their calories (kcals) as done by several researchers (Hunt et al 2020, Savy et al 2007, Wang et al 2021, Benite-Ribeiro et al 2016). Food items from the 3-day food log were converted from grams to kilocalories using The Complete Book of Food Counts (Netzer, 2011) and averaged for potential significance. All carbohydrates and proteins were calculated at 4 kilocalories per gram and fats were calculated at 9 kilocalories per gram. Foods were categorized into 3 macronutrients; carbohydrates included fruits, vegetables, grains, legumes, and tubers. Proteins included meats, fish, and dairy and fats included both saturated and unsaturated fats such as nuts, seeds, oils, nut butter and avocados.

Statistical analysis

Statistical analyses were performed by using SPSS software (IBM SPSS Statistics for Windows, Version 23.0.). Levene's Test for Equality of Variances was used to assess equal variance, and independent t-test (two-tailed) was used to compare base and top athletes. For variables that presented equal distribution, Pearson correlation was used to assess association. Spearman correlation was used for variables that did not present equal distribution. If significance was found, linear regression controlling by position would be performed. The significant alpha value was set for p< 0.05.

Groups/Variables	Top	Base	Significance (p-value)
Age (Years old)	19.6±1.7	19.3±1.2	0.6
Weight (Kg)	54.7±3.1	70.5±9.1	<0.001*
Height (cm)	158.4 ± 6.5	164.6 ±4.4	0.004*
BMI (kg/m2)	21.8± 1.64	26.1 ± 3.1	<0.001*
Carbohydrate Intake (kcal)	744.4± 231.6	859.7± 601.5	0.29
Protein Intake (Kcal)	266.5± 78.7	297.1± 94.0	0.206
Fat Intake (kcal)	583.8± 81.7	644.1± 236.4	0.225
Total calorie Intake (Kcal)	1594.8± 321.0	1658.0± 552.8	0.36
Average Arm Fat (lbs)	1.1± 0.4	2.0± 1.0	0.04*
Average Leg Fat (lbs)	3.4± 0.9	4.9± 1.4	0.03*
Truncal Fat (lbs)	9.4± 3.8	18.6± 7.0	<0.001*
Basal Metabolic Rate	1338.4± 80.3	1476.1± 82.8	0.02*
SMI	19.6± 3.7	19.6± 3.7	0.005*
Vertical Jump (in)	19.6± 3.7	19.2± 5.0	0.83

Table 1. Top and base athletes' characteristics. Age, weight, height, and body mass index (BMI); the average of three days of carbohydrate, protein, fat and total calories intake; the average of both legs and arms fat weigh; truncal fat weight; basal metabolic rate; skeletal muscle index (SMI); vertical jump. Data are expressed as mean± standard deviation. *p<0.05

Results

Athletes from A&T characteristics such as age, body mass index (BMI), weight, height, nutritional behavior, average of the fat weight of legs and arms, basal metabolic rate, skeletal muscle index (SMI) and vertical jump are presented in table 1. When comparing top and base there was no difference between age, vertical jump, three-day average of carbohydrate, protein, fat and total calorie intake; however, height, weight, BMI, weight of fat in arms, legs and trunk, SMI, and basal metabolic rate were higher in base when compared to top (Table 1).

Balance was quantified as how much time the athletes could hold the position in a handstand in seconds. No difference between groups was found in balance (10.6±14.4 in base versus 26.4±26.3 in top, p=0.08, Figure 1). Moreover, the percentage of body fat was higher in base athletes compared to top athletes being 25.8±7.4 % in base versus 19.1 ±4.51 % in top (Figure 2A). There was no difference in the percentage of muscle between the two groups (44.8±2.6 % in top versus 42.4±3.8 % in base) as shown in figure 2A. When stratified by segment the percentage of truncal fat was lower in the tops athletes (7.78±2.94%) compared to the base (12.09±3.62) as shown in figure 2B. Regarding the percentage of fat in legs and arms, no difference between positions was found respectively for base and top arms 1.31±0.53% vs. 0.90±0.35%, and legs 3.26±0.69% vs. 2.82±0.69% (Figure 2C).

When testing the association of variables to balance, the percentage of muscle in the body was positive associated with balance (r=0.46, p<0.05). The percentage of fat in the body, and the percentage of fat in the legs were negatively associated to balance (r=- 0.47, r=- 0.45, p<0.05, respectively) (Table 2). No significant relationship was found between balance and other variables analyzed in this study (Table 2). Moreover, no association was found between vertical jump and BMI, the percentage of muscle and fat, fat distribution, basal metabolic rate, SMI and nutritional behavior (Table 3).

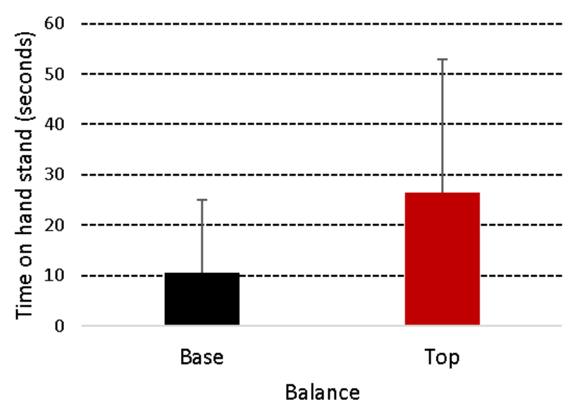

Figure 1. Balance was assessed as time (in seconds) in holding a handstand. Acrobatic and tumbling athletes was separated in their respective positions either base or top. Data is represented as mean ± standard deviation.

Nutritional behavior was assessed by a three-day food log and the average of the macronutrients was calculated. No associations were found between the intake of macronutrients (carbohydrate, fat and protein) and collected variables as shown in Table 3.

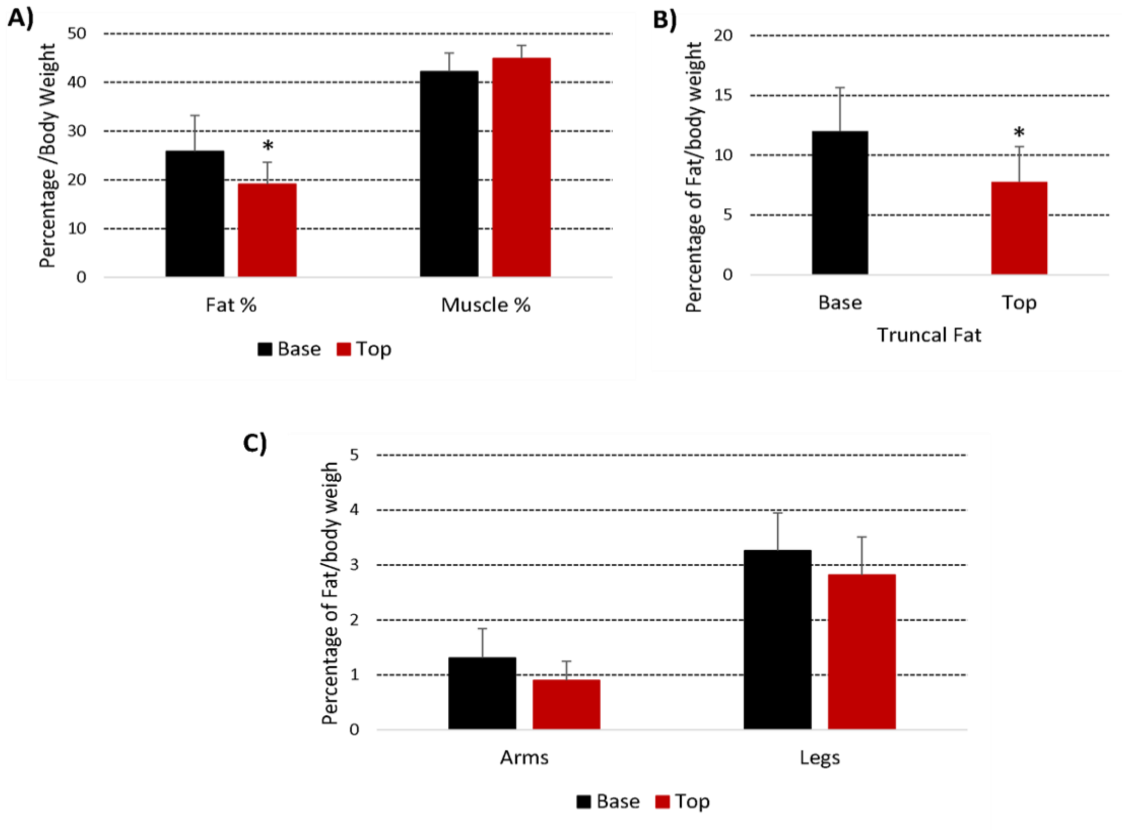

Figure 2. A. Percentage of fat and muscle in top and base in acrobatic athletes. Percentage of fat at truncal **(B)** arms and **(C)** legs areas. Data are represented as mean ± standard deviation. *p < 0.05 compared to base.

Variables	Balance (sec)	Vertical jump (in)
BMI (kg/m2)	-0.34	-0.34
Carbohydrate Intake (kcal)	-0.03	-0.14
Protein Intake (Kcal)	0.13	-0.36
Fat Intake (kcal)	-0.1	-0.25
Total calorie Intake (Kcal)	0.11	-0.35
Average Arm Fat (lbs)	-0.29	-0.28
Perc. Arm Fat (% BW)	-0.44	-0.25
Average Leg Fat (lbs)	-0.35	-0.36
Perc. Arm Leg (%BW)	-0.48*	-0.16
Perc. of Fat	-0.47*	-0.21
Perc. of Muscle	0.49*	-0.01
Truncal Fat (lbs)	0.33	-0.33
Perc. Truncal Fat (%BW)	0.38	0.14
Basal Metabolic Rate	0.06	0.18

Table 2. The association between collected parameters balance, assessed as time (in seconds) in holding a handstand, and vertical jump (inches) was tested by Pearson correlation. Data are expressed as correlation coefficient "r". *p<0.05.

Since body percentage of fat and skeletal muscle, fat percentage in legs were found associated with balance, the association were further tested by linear regression. Because sport position, either top or base, played a role on tested variables, such condition was used as controlling variable in linear regression. As shown in table 4, linear regression confirmed Pearson correlation results that percentage of fat, fat content in legs and percentage of muscle were associated with balance. However, when position was used as a controlling factor, no significance was found. Therefore, correlation between percentage of fat and muscle, fat content in legs with balance were tested by Pearson correlation (balance with percentage of fat or muscle) or Spearman's rank correlation (balance with percentage of fat in legs) within groups. Significance was found in percentage of fat and muscle only in tops not in base athletes (Table 5). No significance association between balance and fat content in legs was found (Table 5).

Variables	Carbohydrate Intake (kcal)	Protein Intake (Kcal)	Fat Intake (kcal)	Total calorie Intake (Kcal)
BMI (kg/m2)	0.02	-0.06	0.19	0.05
Average Arm Fat (lbs)	-0.01	-0.05	-0.02	0.06
Perc. Arm Fat (% BW)	-0.01	-0.1	-0.07	-0.05
Average Leg Fat (lbs)	0.03	-0.04	0.01	0.06
Perc. Leg Fat (%BW)	0.04	-0.15	-0.07	-0.13
Percentage of Fat	-0.04	-0.04	0.15	-0.02
Perfentage of Muscle	0.04	0.16	0.13	0.16
Truncal Fat (lbs)	0.08	0.01	0.05	-0.01
Perc. Truncal Fat (%BW)	0.08	0.001	0.05	-0.01
Basal Metabolic Rate	0.06	0.23	0.3	0.2
SMI	0.18	0.21	0.26	0.22

Table 3. The association between collected parameters with carbohydrate, fat, protein intake and total calories (Kcal) were tested by Pearson correlation. Data are expressed as correlation coefficient "r".

Discussion

A&T is an emerging sport performed by female athletes and attracting several universities around North America; however, there is a lack of analysis of A&T athletic performance in this sport. Therefore, in the present study, we evaluated the difference between the balance in top and base athletes and body composition, fat distribution, and nutritional behavior. The results presented here show differences in body composition and fat distribution among positions in A&T despite no changes in nutritional behavior. Also, balance, not vertical jump, was associated with body composition and fat distribution and those factors are associated manly with top A&T athletes not base.

There are several tests to assess balance and equilibrium in sports; however, the time holding a handstand is the most widely used test for gymnastics and A&T for recruiting purposes. Handstand, a fundamental skill in several sports, is the act of keeping the body in an inverted vertical stance with one or two hands in contact with the support surface. For those reasons, several studies were performed to identify variables linked to achieving the best technique to hold an upright posture and handstand for a long time (Wyatt et all 2021). A study by Mizutori and colleagues (2021) found that straight arm press to handstand techniques were the most critical aspect of performing movements and keeping a static position in a handstand (Mizutori et al, 2021). Moreover, it was found in gymnastics that the maximal power of the lower limbs tested on a force plate showed a positive correlation with the judges' score for the front handstand vault (Kochanowicz et al. 2016). Thorland et al. suggested that specific features of gymnasts' body composition and body type typically justified how successful and proficient the athlete was (Thorland et al., 1981). Moreover, the results of this study support that an increase in overall body muscle percentage and a decrease in fat, particularly at lower limbs, play a major role in balance performance in A&T since an association was found between the variables.

Body compositions and anthropometric characteristics are critical factors in determining a person's capability to reach professional levels in a determinate sport, and it is also essential determinant for the assignment of athletes' position (Gerodimos et al, 2005; Fullagar, McCunn & Murray, 2022). In sports like American Football, body fat, and muscle mass vary tremendously depending on the position (Fullagar, McCunn & Murray, 2022). When elite gymnasts were compared on different competitive levels, the highest-ranked gymnasts tended to have a lower body composition associated with the performance (Classens et al 1990). Since in A&T, most of the athletes are former gymnastics, it is expected that A&T has similar characteristics to gymnastics, such as small size, low body mass, and low-fat mass (Bacciotti, Baxter-Jones, Gaya & Maia, 2017). However, while A&T top athletes present such a phenotype, base athletes have higher BMI, weight, height, and fat percentage. Therefore, the percentage of fat and muscle and the percentage of fat in the legs could be a tool to determine the position of A&T athletes since when the relationship was tested in the different positions, the percentage of muscle and fat was associated with balance only in A&T top athletes.

Several studies demonstrate that nutrition intervention to improve athlete performance and that specific types of feeding behavior, such as high protein intake and low carbohydrate and fat, play an essential role in muscle mass and performance (Nacimento et al 2016; Vitale et al. 2019, Skinner et

	Regression coefficient from simple linear regression models				Regression coefficient from linear regression models, controlling for position			
Explanatory variables	Unstandardized B	*SE*	P-value	R Square	Unstandardized B	*SE*	P-value	R Square Change
Perc. Muscle	2.795	1.113	.019*	.208	2.258	1.188	.07	.048
Perc. Body Fat	-1.42	.547	.016*	.219	-1.141	.623	.08	.029
Perc. Fat Leg	-15.945	7.463	.05*	.233	-13.864	7.936	.103	.037

Table 4. Linear Regression of Percentage (Perc.) of muscle and fat and percentage of fat in the leg not adjusted or controlled for position (wither top or base) *p<0.05.

al 2020, Riffee et al 2023). In this study, no correlation was found between nutritional behavior with body composition or performance measure by a three day-food log. The reason for such a result might be that A&T athletes have a heavy training routine that compensates for diet. Nevertheless, the questionnaire's inaccuracy could also be a factor to consider. Cleland et al. (2018) tested the accuracy of the International Physical Activity Questionnaire (long-form) by tracking older adults' physical activity for seven consecutive days and then having them complete the questionnaire. When the results of both tests were compared, they revealed that the participants underestimated their level of sedentary behavior (Cleland et al 2018). Therefore, the participant may not accurately perceive their nutritional behavior. Therefore, this matter still requires further investigation in A&T athletes.

A&T is a competitive sport that has grown every year. To our knowledge, this is the first study that analyzed A&T athletes' characteristics and performance. In summary, the results of this study indicate that body composition can be used to assign the athlete's position in A&T and that the percentage of fat and muscle could be directly associated with performance of A&T athletes on the position of top when the balance is assessed. Moreover, the results strengthen the hypothesis that when analyzing different segments, the low percentage of fat in the legs is more critical than that in the arms and truncal for improving handstand time and performance. Strategies to decrease fat concentration and increase muscle mass could a valuable approach to improve performance of athletes in A&T.

Variables/correlation coef. (r or ρ)	Top	Base
Perc. Muscle	r=0.67*	r=0.18
Perc. Body Fat	r=-0.62*	r=-0.25
Perc. Fat Leg	ρ=-0.57	ρ=-0.38

Table 5. Correlation of balance with body percentage of muscle and fat, and percentage of fat in legs. Analyses were carried out within groups. "r" for Pearson and 'ρ' for Spearman. *p<0.05.

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