Title

Assessing the beliefs and impacts of strength training in a Division I collegiate gymnastics team

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Assessing the Beliefs and Impacts of Strength Training in a Division I Collegiate Gymnastics Team

Abstract

Introduction: Traditionally, there has been a reluctance to utilize weight training with female gymnasts due to concerns that it could cause detrimental increases in muscle mass and impede flexibility.[14] However, recent literature has demonstrated that strength training has no significant effect on flexibility and can improve athletic performance.[16,17]

Objective: This pilot study assessed collegiate gymnasts and coaches' perceptions toward strength training after starting inaugural strength and conditioning training.

Design: Survey-based study

Setting: National Collegiate Athletics Association Division I women's gymnastics program at a public university in California

Participants: Of the 23 gymnasts surveyed, 17 (74%) responded to the survey. Of the 2 coaches surveyed, both (100%) responded to the survey.

Interventions: Not applicable

Main Outcome Measures: Descriptive statistics characterizing demographics, characteristics of gymnasts' strength and conditioning program, and perceptions regarding the safety of strength training and its impact on performance, body shape, and flexibility, injury rates

Results: Most gymnasts agreed (35%) or strongly agreed (59%) that weight training may improve performance. All gymnasts disagreed (59%) or strongly disagreed (41%) that weight training is not safe. 41% disagreed, 29% strongly disagreed, and 17% agreed that weight training may negatively impact body shape. Most gymnasts disagreed (59%) or strongly disagreed (18%) that weight training decreases flexibility; four (24%) felt neutral. 83% (59% strongly agree, 24% agree) felt that weight training had positive impact on performance. More than half of the gymnasts either agreed (24%) or strongly agreed (29%) they had less injuries the season after implementing weight training, compared to prior seasons. Both coaches similarly endorsed the safety of strength training and its potential to improve performance.

Conclusions: In this pilot study, collegiate gymnasts and coaches expressed generally positive perceptions toward the safety of strength training and its impact on performance. Still, a small number of gymnasts expressed concerns regarding the effects of weight training on body shape and flexibility.

Key words:

Gymnastics

Female athlete

Collegiate sport

46 Strength training
47 Weight training
48 Conditioning

Introduction

Gymnastics is regarded as one of the most difficult and technical sports in the world, requiring athletes to possess high levels of balance, strength, flexibility, proprioception, grace, discipline, and grit.[1] Gymnastics is a year-round sport requiring early specialization, with most athletes becoming single-sport athletes at, or before, nine years of age.[2]

On average, competitive gymnasts train more than 15 hours per week, with elite and collegiate levels training 25-40 hours per week, leading to hundreds of skills performed each practice [2,3,9] Gymnasts load joints at extreme angles and torques, with axial, rebound and rotational forces 3-10 times body weight leading to high impacts to both the lower and upper extremities.[1,5-8] These factors contribute to a high propensity for injury. The National Collegiate Athletic Association (NCAA) found women's artistic gymnastics to have the second highest injury rate in practice, surpassed only by football.[3]

Weight training and non-sport training are integral components of total exercise prescription of multiple collegiate and elite sports and have been associated with injury reduction and improved performance.[10–13] In a 2000 survey of gymnasts, coaches, and administrators in the United States, consensus indicated weight training in gymnastics “produces detrimental increases in muscle mass, loss of flexibility, or impediment of movements that require extreme flexibility.”[14] Multiple variables, including this perception of weight training, have led to decreased adoption of formal weight training in gymnastics..[4,15]

Since 2010, a growing body of evidence demonstrates clear improvements in strength, power, and even flexibility[16,17] in gymnasts who strength train, with little change to body composition.[16–18] While weight training and non-sport training are becoming more accepted within collegiate and elite gymnastics, "few intervention studies have been published within the field of gymnastics injury prevention."[19,20] At the [CENSORED FOR BLINDED REVIEW] Division I gymnastics program, a coaching change led to initiation of strength training with a certified strength and conditioning coach (CSCS). Consequently, we utilized this opportunity to assess collegiate gymnast and coach perceptions regarding strength training for injury prevention, while tracking longitudinal injury rates after starting formal strength training.

Methods

Survey Design

This study was conducted at [CENSORED FOR BLINDED REVIEW], a public university that offers a NCAA Division I women's gymnastics program. The study was approved by the [CENSORED FOR BLINDED REVIEW] Institutional Review Board (IRB). An electronic anonymous survey, created using Qualtrics® (web-based survey software), was distributed via email to twenty-three gymnasts and three coaches on the team during the 2024 competition season. In compliance with the Health Insurance Portability and Accountability Act (HIPAA) and Family Educational Rights and Privacy Act (FERPA), gymnasts signed a consent form prior to completing the survey via DocuSign®, a web-based software tool approved by the [CENSORED FOR BLINDED REVIEW] IRB for research and written consent. Survey responses were collected August through September 2023.

Survey Measures

The survey was designed to assess collegiate gymnasts' perceptions regarding strength training after starting their inaugural training with a CSCS. Gymnasts were asked to share demographic data, such as their current age, the age at which gymnastics became their primary sport, other sports they have participated in, and the number of years they have participated in competitive gymnastics. To characterize their weekly training plan, gymnasts were asked to specify the number of gymnastics training sessions per day, average number of hours of gymnastics training per session, average number of strength and conditioning sessions per week, and average number of minutes of strength and conditioning training per session. Gymnasts were also asked to identify who created and implemented their strength and conditioning program and describe the components of the strength and conditioning program by specifying the average percentages of aerobic exercise, resistance training with weights, resistance training with weights or body weight, agility and power training, and body shaping exercises. Finally, the gymnasts and their coaches were surveyed on their perceptions toward weight training regarding safety and impact on performance, body shape, and flexibility. Gymnasts and coaches were also asked if they noted changes in injury rates, or performance, since starting formal strength training. A Likert-scale was utilized to assess agreement with each statement.

Competition Performance Data Collection

To evaluate for improvement in performance after the gymnasts started training with a CSCS, competition scores from the 2023 competition season (prior to implementation of strength and conditioning training) and 2024 competition season (after implementation of training) were collected. Competition scores, which are available to the public on the [CENSORED FOR BLINDED REVIEW] athletics website, were recorded for all athletes who competed during both the 2023 and 2024 competition seasons. Each individual gymnast could participate in any combination of four women’s gymnastics apparatuses: vault, uneven bars, beam, and floor exercise. Individual scores for each apparatus, along with season average scores and season-high scores for each apparatus were collected for all competitions.

Statistical Analysis

Descriptive and summary analyses were performed to determine the frequency, central tendency, and variation in demographic characteristics, weekly training plans, and components of strength and conditioning programs based on the survey. Descriptive statistics were generated to examine the frequency and percentages to which gymnasts agreed with statements pertaining to their perceptions toward weight training.

To evaluate the effect of strength training on competition performance, we used mixed effects regression models, both unadjusted and adjusted for apparatus. We compared least squares means to evaluate differences in competition performance scores across the 2023 (pre-strength training) and 2024 (post-strength training) seasons, both unadjusted and adjusted by apparatus (vault, uneven bars, beam, floor). Paired t-tests were performed to evaluate differences in mean individual season average scores and mean individual season-high scores between across the 2023 and 2024 seasons. All analyses were performed using SAS® software version 9.4 for Windows®.

Results

Demographic Characteristics

Of the 23 gymnasts surveyed, 17 responded to the survey (74% response rate). The mean age of the survey respondents was 19.9 years (SD=1.5 range=18-22) and median age 20 years. The mean age at which gymnastics became their primary sport was 7 years (SD=1.7, range=5-12) and median age 7 years. Most gymnasts (n=12, 71%) had participated in another sport at some point in their career. Those most common sports were dance (n=6), swimming (n=4), soccer (n=3), and tennis (n=3). 29% of survey respondents (n=5) had only participated in gymnastics. The distribution of participation in other sports is shown in Table 2. The mean and median number of years that the gymnasts had spent participating in competitive gymnasts was 13 years (SD=2.1, range=8-17; Table 1).

Weekly Training Plan Characteristics

All gymnasts reported participating in one gymnastics training session per day, spending, on average, 4 hours (SD=0.4, range=3-5, median=4) on each training session. All gymnasts participated in strength and conditioning, with a mean of 2.74 (SD=1.2, range=2-5, median=2) sessions per week, lasting, on average, 55.6 (SD=10.3, range=30-60, median=60) minutes per session (Table 1).

Strength and Conditioning Program Components

Most gymnasts surveyed had a strength and conditioning program created and implemented by their head coach (n=11) or strength and conditioning coach outside their gym (n=10). Others had programs created by assistant coaches, strength and conditioning coaches in the gymnasts' gym, or athletic trainers. The distribution of those creating and implementing the gymnasts' strength and conditioning programs is shown in Table 3. The average program components were 14.9% (SD=11.3, range=0-35, median=10) aerobic exercise, 43.5% (SD=29.4, range=0-100, median=40) resistance training with weights, 28.3% (SD=29.5, range=0-100, median=16) resistance training with weights or body weight, 23.2% (SD=21.2, range=0-80, median=16) agility and power training, and 24.1% (SD=27.5, range=0-100, median=10) body shaping exercises (Table 1).

Perceptions Toward Weight Training

Most gymnasts agreed (35%, n=6) or strongly agreed (59%, n=10) that weight training may improve performance (Figure 1). All gymnasts either disagreed (59%, n=10) or strongly disagreed (41%, n=7) that weight training is not safe (Figure 2). 41% (n=7) disagreed, 29% (n=5) strongly disagreed, and 17% (n=3) agreed that weight training may negatively impact body shape (Figure 3). Most gymnasts either disagreed (59%, n=10) or strongly disagreed (18%, n=3) that weight training decreases flexibility (Figure 4); four (24%) felt neutral. Most gymnasts (59%, n=10, strongly agree; 24%, n=4, agree) felt that weight training had a positive impact on performance (Figure 5). More than half of the gymnasts either agreed (24%, n=4) or strongly agreed (29%, n=5) they had less injuries the season after implementing strength training, compared to prior seasons (Figure 6). Responses to questions regarding perceptions toward weight training are summarized in Table 4.

Both coaches (n=2) surveyed had similar perceptions. They agreed weight training has the potential to improve performance and believed weight training positively impacted their gymnasts' performance during the past year; one coach strongly agreed with both statements. Both coaches disagreed with the statements that weight training is not safe for gymnasts and that it makes gymnasts less flexible; one coach strongly disagreed with both statements. The coaches took a neutral stance on whether weight training may negatively impact body shape. However, while one coach agreed that the gymnasts had less injuries during the season after implementing strength training, compared to prior seasons, the other coach took a neutral stance on this statement, explaining that “it's a little too soon to tell how weight training has affected their injuries.”

Competition Performance Pre- and Post-Strength Training

Although there were 23 gymnasts on the 2023 season roster, only 9 gymnasts competed during both the 2023 and 2024 competition seasons. We observed a non-statistically significant ($p=0.30$) unadjusted average difference in scores of -0.03 between the 2023 (pre-strength training) and 2024 (post-strength training) seasons. Least squares means and standard errors were used to evaluate differences in scores between the 2023 and 2024 seasons, both unadjusted and adjusted by apparatus. The unadjusted least squares means demonstrated a slight, statistically significant decrease in scores between the 2023 and 2024 seasons ($p=0.30$). Least squares means adjusted by apparatus demonstrated significantly improved beam scores ($p_{interaction}=0.03$) between the 2023 and 2024 seasons, slightly worse floor exercise scores between the 2023 and 2024 seasons, no change in vault scores between the 2023 and 2024 seasons, and significantly worse uneven bars scores between the 2023 and 2024 seasons (Table 5). The effects of strength training on event scores by apparatus across the 2023 and 2024 competition seasons are illustrated in Figure 7. Descriptive statistics for season average scores and season-high scores by apparatuses during the 2023 and 2024 seasons are summarized in Table 6 and Table 7, respectively. Paired t-tests showed no statistically significant differences in individual season average scores or individual season-high scores by apparatuses between the 2023 and 2024 seasons (Table 9).

Discussion

Significance

In the past, strength training was deemed detrimental to athletic performance, due to concern that it would make athletes stiff and slow.[21] Recent literature has disproven these taboos however, demonstrating that strength training has no significant effect on flexibility[22] and even improves running economy[23] and vertical jumping performance.[24] The subjective experiences of most gymnasts and both coaches surveyed in this study are consistent with recent literature, endorsing that weight training had a positive impact on their athletic performance without decreased flexibility. All gymnasts and both coaches we surveyed endorsed the safety of weight training. However, while most gymnasts disagreed with the belief that weight training may negatively impact body shape, a few gymnasts, and both coaches, took a neutral stance on this statement, hinting at a lingering stigma surrounding the effect of weight training on traditional perceptions of a "feminine" figure.

A little over half the gymnasts surveyed perceived they had fewer injuries during the season in which a formal strength training program was implemented; most of the remaining gymnasts had a neutral stance on injury risk during the season. There is limited research on the effects of strength training on injury prevention in gymnastics, however, conditioning models that incorporate resistance training have shown promise in reducing injury risk among athletes.[28] Neuromuscular training, in particular, which combines sport-specific and fundamental movements training,[29] has been found to decrease incidence of knee injuries in female athletes.[30,31]

The majority of the surveyed group felt strength training had a positive impact on their performance and demonstrated a willingness to incorporate strength training into their conditioning, no significant improvement in overall (unadjusted) competition scores was observed in the 2024 season compared to the 2023 season. However, when adjusted by apparatus, we observed differences in 2023-2024 competition scores. Of the four apparatuses, beam scores demonstrated a statistically significant improvement between the 2023 and 2024 seasons. Interestingly, a statistically significant decrease in competition scores was observed for uneven bars during the 2024 season. This paradoxical finding might be attributable to the wide score range throughout the 2024 season due to multiple falls off the apparatus, which caused large score deductions.

The lack of significant change in overall (unadjusted) competition performance scores may be explained by multiple factors. First, strength and conditioning training had only recently been implemented prior to the 2024 competition season; a longer period of strength training may be needed to observe positive impacts on performance. Second, competition performance scores may not be sensitive to subtle improvements perceived by the gymnasts. Finally, this performance data was drawn from a small sample size (N=9), which may lack sufficient power to detect an effect.

Limitations

Although we achieved an excellent survey response rate of 74%, the sample size was small. Additionally, only nine gymnasts competed in both the 2023 and 2024 competition seasons, limiting the statistical power to analyze competition scores pre- and post-strength training.

Furthermore, as the survey was performed at a single institution, the results may have limited generalizability.

A key limitation of this study is the use of an unvalidated survey. To our knowledge, there is currently no existing validated survey tool that evaluates athletes' perceptions toward strength training. Thus, this pilot study utilized a survey developed by the current head team physicians for the USA Gymnastics Women's National Team to assess perceptions toward strength training among gymnasts. Importantly, this survey was administered at a pivotal point in time: during the gymnasts' transition from traditional gymnastics training to training that incorporated a formal strength and conditioning program. If the study investigators had waited until a validated survey tool was available for use, they would have missed the opportunity to assess gymnasts' perceptions towards weight training during this unique transition point.

Survey studies are also inherently limited by subjectivity. Although all survey respondents belonged to the same gymnastics team, there was wide variability in descriptions of their weekly training plans and components of their strength and conditioning programs. While this variability may have been due, in part, to intentional individualization, it may also reflect recall bias. Further, several survey questions relied on subjective impressions, such as whether the gymnasts experienced fewer injuries the season after implementing strength training, rather than objective data.

Conclusions

In a single-center survey, the majority of gymnasts and all the coaches expressed positive perceptions of the safety of weight training and its potential to improve performance and decrease injury risk. Many gymnasts expressed positive perceptions regarding the effect of weight training on body shape and flexibility, only a few gymnasts expressed concerns. This survey also revealed mixed opinions regarding the role of weight training in injury prevention. Although most gymnasts felt strength training had a positive impact on athletic performance, no significant change in overall competition scores were observed after implementation of a strength and conditioning program.

Further research is needed to develop a validated survey tool for assessing athletes' perceptions toward strength training and to establish evidence-based, standardized, gymnastics-specific strength and conditioning programs that benefit both performance and injury prevention. Power and generalizability of results may be improved by surveying teams across multiple institutions. Additional collection and assessment of prospective injury data could enhance correlation of injury risk with the implementation of strength and conditioning programs, specifically looking at time loss injuries. Longer term evaluation of competition scores may provide stronger insight into the effects on athletic performance. Finally, expansion to include men's gymnastics programs could enable evaluation of potential differences between male and female gymnasts.

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Table 1. Descriptive Statistics of Demographic Characteristics, Weekly Training Plan Characteristics, and Strength and Conditioning Program Components (N=17)

Variable	Mean	Std Dev	Median	Minimum	Maximum
Age	19.94	1.48	20	18	22
Age when gymnastics was primary sport	7	1.73	7	5	12
Years in competitive gymnastics	13	2.09	13	8	17
Average hours per training session	3.97	0.37	4	3	5
Average number of strength/conditioning sessions per week	2.74	1.20	2	2	5
Average minutes per strength/conditioning session	55.59	10.29	60	30	60
Average percentage of aerobic exercise	14.94	11.29	10	0	35
Average percentage of resistance training with weights	43.47	29.43	40	0	100
Average percentage of resistance training with weights or body weight	28.29	29.54	16	0	100
Average percentage of agility and power training	23.18	21.23	16	0	80
Average percentage of body shaping exercises	24.06	27.45	10	0	100

Table 2. Distribution of Participation in Other Sports (N=27)†

Sport	Frequency	Percentage
Dance	6	22%
Swimming	4	15%
Soccer	3	11%
Tennis	3	11%
Basketball	2	7%
Cheerleading	1	4%
Diving	1	4%
Surfing	1	4%
Volleyball	1	4%
None	5	19%

†Although 17 survey responses were received, each gymnast could participate in multiple sports, hence the N of 27

Table 3. Distribution of Who Created and Implemented Gymnasts' Strength and Conditioning Program (N=30)†

Position	Frequency	Percentage
Head coach	11	37%
Strength & conditioning coach outside my gym	10	33%
Another coach	4	13%
Strength & conditioning coach in my gym	3	10%
Athletic trainer	2	7%
Physical therapist	0	0%
I don't know	0	0%
Other	0	0%

†Although 17 survey responses were received, multiple people could create/implement a gymnast's strength and conditioning program, hence the N of 30

Table 4. Survey Responses to Perceptions Toward Weight Training (N=17)

Perception Statement	Frequency	Percentage
Weight training may improve gymnastics performance		
Strongly Disagree	0	0%
Disagree	1	6%
Neutral	0	0%
Agree	6	35%
Strongly Agree	10	59%
Weight training is not safe for gymnasts		
Strongly Disagree	7	41%
Disagree	10	59%
Neutral	0	0%
Agree	0	0%
Strongly Agree	0	0%
Weight training may negatively impact a gymnast's body shape		
Strongly Disagree	5	29%
Disagree	7	41%
Neutral	2	12%
Agree	3	18%
Strongly Agree	0	0%
Weight training will make a gymnast less flexible		
Strongly Disagree	3	18%
Disagree	10	59%
Neutral	4	24%
Agree	0	0%
Strongly Agree	0	0%
Do you feel that weight training had a positive impact on your performance this year?		
Strongly Disagree	0	0%
Disagree	1	6%
Neutral	2	12%
Agree	4	24%
Strongly Agree	10	59%
Do you feel that you have had less injuries during this season, than during prior gymnastics seasons?		
Strongly Disagree	0	0%
Disagree	1	6%
Neutral	7	41%
Agree	4	24%
Strongly Agree	5	29%

Table 5: Least Squares Means and Standard Errors for Differences in Scores, Unadjusted and Adjusted by Apparatuses

Adjusted by Apparatus				Unadjusted		
Apparatus	**2023 Season (Pre-strength training)**	**2024 Season (Post-strength training)**	$p_{interaction}$	**2023 Season (Pre-strength training)**	**2024 Season (Post-strength training)**	**p-value**
Vault	9.71 (0.06)	9.71 (0.06)	0.03	9.67 (0.04)	9.64 (0.04)	0.30
Uneven Bars	9.70 (0.06)	9.51 (0.06)				
Beam	9.55 (0.06)	9.62 (0.05)				
Floor Exercise	9.75 (0.06)	9.72 (0.05)				

Table 6. Descriptive Statistics for Season Average Scores by Apparatuses During the 2023 and 2024 Seasons

Season	Apparatus	N	Mean	Standard Deviation	Minimum	Maximum
2023 (Pre-strength training)	Vault	5	9.77	0.05	9.71	9.82
	Uneven Bars	6	9.69	0.04	9.65	9.76
	Beam	6	9.54	0.24	9.28	9.84
	Floor Exercise	6	9.72	0.14	9.53	9.84
2024 (Post-strength training)	Vault	5	9.74	0.14	9.50	`9.83
	Uneven Bars	6	9.46	0.35	8.91	9.83
	Beam	6	9.58	0.15	9.33	9.70
	Floor Exercise	6	9.72	0.18	9.38	9.86

Table 7. Descriptive Statistics for Season High Scores by Apparatuses During the 2023 and 2024 Seasons

Season	Apparatus	N	Mean	Standard Deviation	Minimum	Maximum
2023 (Pre-strength training)	Vault	5	9.86	0.08	9.75	9.93
	Bars	6	9.85	0.04	9.78	9.88
	Beam	6	9.76	0.24	9.28	9.90
	Floor	6	9.80	0.20	9.53	9.98
2024 (Post-strength training)	Vault	5	9.81	0.18	9.50	`9.93
	Bars	6	9.76	0.22	0.33	9.93
	Beam	6	9.86	0.07	9.75	9.95
	Floor	6	9.89	0.06	9.78	9.93

Table 8. Paired T-tests for Differences in Individual Season Average Scores by Apparatuses Between the 2023 and 2024 Seasons

Apparatus	N	Mean	Standard Deviation	Standard Error	Minimum	Maximum	p-value
Vault	5	0.03	0.11	0.05	-0.05	0.22	0.62
Uneven Bars	6	0.23	0.33	0.13	-0.07	0.75	0.14
Beam	6	-0.04	0.24	0.10	-0.41	0.23	0.68
Floor Exercise	6	-0.00	0.12	0.05	-0.19	0.18	0.97

Table 9. Paired T-tests for Differences in Individual Season High Scores by Apparatuses Between the 2023 and 2024 Seasons

Apparatus	N	Mean	Standard Deviation	Standard Error	Minimum	Maximum	p-value
Vault	5	0.05	0.11	0.05	-0.03	0.25	0.38
Uneven Bars	6	0.09	0.19	0.08	-0.08	0.45	0.31
Beam	6	-0.10	0.24	0.10	-0.58	0.05	0.34
Floor Exercise	6	-0.09	0.17	0.07	-0.38	0.05	0.25

Figure 1. Effect of Weight Training on Gymnastics Performance

This figure shows the percentage of gymnasts who agreed with the statement, "Weight training may improve gymnastics performance" based on a 5-point Likert scale.

Figure 2. Safety of Weight Training for Gymnasts
This figure shows the percentage of gymnasts who agreed with the statement, "Weight training is not safe for gymnasts" based on a 5-point Likert scale.

Figure 3. Impact of Weight Training on Gymnast's Body Shape
This figure shows the percentage of gymnasts who agreed with the statement, "Weight training may negatively impact a gymnast's body shape" based on a 5-point Likert scale.

Figure 4. Effect of Weight Training of Gymnast's Flexibility
This figure shows the percentage of gymnasts who agreed with the statement, "Weight training will make a gymnast less flexible" based on a 5-point Likert scale.

Figure 5. Impact of Weight Training on Performance
This figure shows the percentage of gymnasts who agreed with the question, "Do you feel that weight training had a positive impact on your performance this year?" based on a 5-point Likert scale.

Figure 6. Season Injury Rate After Inaugural Strength Training
This figure shows the percentage of gymnasts who agreed with the question, "Do you feel that you have had less injuries during this season, than during prior gymnastics sessions?" based on a 5-point Likert scale.

Figure 7. Effects of Strength Training of Event Score by Apparatus Pre- and Post-Strength Training
Box-and-whisker plot comparing event scores categorized by apparatus between the 2023 (pre-strength training) and 2024 (post-strength training) competition seasons.