Associations between flexibility, aerobic capacity, and training experience among Algerian bodybuilders

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ABSTRACT

This study examined aerobic capacity and flexibility among Algerian bodybuilders and explored their associations with age and training experience. Fifteen male athletes from Batna Province participated in the research. Aerobic capacity was assessed using the Luc Léger 20-m shuttle run test, while trunk flexibility and shoulder mobility were evaluated through the sit-and-reach and back-scratch tests, respectively.

Results showed moderate aerobic capacity and generally low to moderate flexibility across the sample. Correlational analyses revealed no statistically significant relationships between VO_2max, flexibility, age, or training duration ($p > 0.05$). Although flexibility displayed a slight tendency to decline with age and to improve with longer training experience, these trends did not reach significance, likely due to the small and homogeneous sample.

These findings underscore the importance of integrating structured flexibility and aerobic training into bodybuilding programs to maintain optimal mobility and performance. Future studies employing larger and more diverse samples are recommended to better clarify the relationships among age, training experience, and physical fitness components in bodybuilding populations.

KEYWORDS

flexibility; aerobic capacity; bodybuilding; training experience; age

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INTRODUCTION

Bodybuilding is a sport primarily focused on developing muscular strength and hypertrophy, with athletes striving to achieve maximal muscle growth and optimal physical

aesthetics. However, this strong emphasis on muscle size and strength often leads to the neglect of other essential physical attributes, particularly flexibility and aerobic capacity – both of which play a crucial role in optimizing movement efficiency, training quality, and injury prevention.

Flexibility, defined as the ability of muscles and joints to move through a full range of motion, is fundamental for maintaining functional mobility and minimizing injury risk (Alter, 2004). Nevertheless, excessive muscle hypertrophy resulting from resistance training may reduce joint mobility, especially when stretching is not systematically incorporated into training programs. Similarly, aerobic capacity constitutes a key component of overall physical fitness, enabling athletes to sustain repeated efforts, recover efficiently between sets, and tolerate prolonged training sessions (Bird et al., 2006). In bodybuilding, where training volume is typically high and metabolically demanding, inadequate aerobic conditioning may impair recovery and increase fatigue.

Despite the recognized importance of these two components, flexibility and aerobic capacity appear to vary considerably among bodybuilders, influenced by several factors, most notably age and training experience (Bompa & Haff, 2009). However, research addressing these relationships within bodybuilding populations – particularly in North Africa – remains scarce.

Although bodybuilding is widely practiced in Algeria, scientific investigations focusing on functional capacities such as joint mobility and aerobic fitness in this athletic group are extremely limited. Existing literature largely emphasizes strength development, muscle hypertrophy, and nutritional strategies, while neglecting critical aspects related to mobility and cardiorespiratory function. This lack of empirical data creates a clear gap in understanding whether conventional bodybuilding training is sufficient to maintain adequate flexibility and aerobic conditioning. Accordingly, providing baseline descriptive data on Algerian bodybuilders contributes valuable insight to an understudied athletic population and highlights areas that require further scientific attention.

In this context, the present study aims to evaluate the levels of flexibility and aerobic capacity among bodybuilding athletes and to examine the extent to which these parameters vary according to age and training experience.

RESEARCH PURPOSE AND HYPOTHESES

The present study aimed to evaluate the levels of aerobic capacity and flexibility among bodybuilding athletes and to examine their associations with age and training experience. Understanding how these physical attributes vary and interact with key demographic and training variables can provide valuable insights for optimizing performance and preventing functional limitations in bodybuilding practice.

Accordingly, the study formulated the following hypotheses:

1. Bodybuilders would exhibit moderate levels of aerobic capacity.
2. Bodybuilders would demonstrate limited flexibility, particularly in the trunk and shoulder joints.
3. Aerobic capacity and flexibility would show significant relationships with both age and training experience.

RESEARCH METHODOLOGY

A descriptive cross-sectional design was adopted to quantitatively assess aerobic capacity and flexibility among bodybuilding athletes and to examine their relationships with age and training experience. This design enabled the evaluation of existing physical performance indicators in a natural training context without manipulating any variables.

Research sample

The study relied on a purposive sample consisting of 15 male bodybuilding athletes registered in local sports clubs in the Batna. This selection was intentional, as the participants possessed the specific physical and training characteristics required to address the study objectives. All participants were actively engaged in bodybuilding practice for at least three years and were free from any musculoskeletal injuries that could affect performance during testing.

Table 1 Anthropometric and demographic characteristics of the sample

Variable	Categories	Range	Number	Percentage
Age	Category 1	18–22 years	9	60.00%
	Category 2	26–29 years	3	20.00%
	Category 3	≥ 30 years	3	20.00%
Weight	Category 1	60–70 kg	3	20.00%
	Category 2	70–80 kg	5	33.33%
	Category 3	> 80 kg	7	46.66%
Height	Category 1	1.60–1.70 m	3	20.00%
	Category 2	1.71–1.80 m	8	53.33%
	Category 3	> 1.80 m	4	26.66%

Table 1 presents the anthropometric and demographic characteristics of the sample. Most athletes (60%) were between 18 and 22 years old, indicating that the sample primarily represents young adult bodybuilders. In terms of body weight, nearly half of the participants (46.66%) weighed more than 80 kg, reflecting the muscular development typical of bodybuilding practice. Height distribution showed that 53.33% of athletes were between 1.71 m and 1.80 m, while 26.66% exceeded 1.80 m. Overall, the sample demonstrates diverse anthropometric characteristics while maintaining similar training backgrounds.

Research tools

In this study, a set of standardized physical fitness tests was employed to collect quantitative data related to endurance and flexibility among bodybuilding athletes. The following tools were used:

Aerobic capacity assessment – Léger-Boucher (Beep) Test

Aerobic capacity (VO_2max) was estimated using the 20-meter multistage shuttle run test, also known as the Léger-Boucher or "Beep Test" (Léger & Boucher, 1980). Participants ran between two lines 20 meters apart in synchronization with audio signals that increased in frequency each minute. The test ended when an athlete failed to reach the line twice consecutively or voluntarily stopped due to exhaustion.

The last completed level and number of shuttles were used to estimate VO_2max using validated predictive equations (Ramsbottom et al., 2001). This protocol is widely recognized for its reliability in trained populations and is appropriate for estimating aerobic capacity in strength athletes.

Flexibility assessment – Forward Flexion Test

The Forward Flexion Test was used to assess trunk and hamstring flexibility. Participants stood upright with knees fully extended and slowly bent forward to reach toward the floor without bouncing. The vertical distance between the fingertips and the floor was measured in centimeters:

- **Positive values:** fingers below floor level
- **Zero:** fingers touching the floor
- **Negative values:** fingers above floor level

This test serves as a valid indicator of posterior chain flexibility.

Back-Scratch Test (Rikli & Jones, 1999)

Shoulder joint mobility was evaluated using the Back-Scratch Test. Participants placed one arm over the shoulder and the other upward behind the back, attempting to touch or overlap the middle fingers. The distance between the fingertips (overlap or gap) was measured in centimeters. Each side was tested, and the best score was recorded. This test is widely used to assess upper-body flexibility and functional range of motion.

STATISTICAL TOOLS

All statistical analyses were performed using SPSS version 26. Descriptive statistics (means, standard deviations, and percentages) were calculated to summarize the characteristics of the sample and the results of the physical fitness tests. Pearson's correlation coefficient (r) was used to examine the relationships between aerobic capacity (VO_2max), flexibility measures, age, and training duration.

Given the small sample size ($n = 15$), the statistical power of the tests was limited, reducing the likelihood of detecting significant associations even when meaningful relationships may exist. For this reason, the correlation results are interpreted cautiously. Confidence intervals for correlation coefficients were not included because the small sample size would produce wide intervals with limited interpretive value; however, the absence of significance ($p > 0.05$) is explicitly reported for all analyses.

All statistical tests were conducted at a significance threshold of $p \leq 0.05$. Due to the exploratory nature of the study and the limited sample size, the analysis focused on identifying general trends rather than making strong inferential claims. Future studies with larger and more diverse samples are needed to validate the observed trends and provide more robust statistical conclusions.

PRESENTATION, ANALYSIS, AND DISCUSSION OF RESULTS

Presentation and analysis of results related to the first hypothesis

Aerobic capacity (Luc Léger Test)

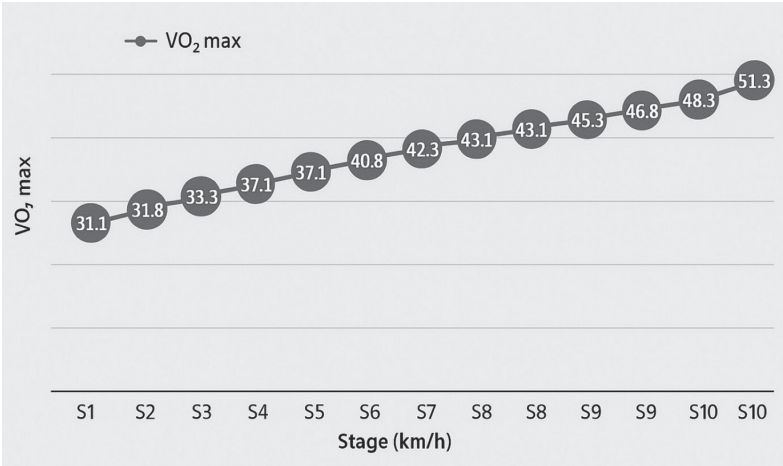

Figure 1 Curve illustrating the variations in maximal aerobic capacity (VO_2max) as a function of speed (km/h).

Table 2 Results of the maximal aerobic capacity test (VO_2max)

Stage	S1	S2	S3		S4		S5	S6		S7		S8		S9		S10	
Vo_2max	/	/	31.1	31.8	33.3	34.8	37.1	37.8	40.8	42.3	43.1	43.8	45.3	46.8	48.3	49.1	51.3

Figure 1 and Table 2 present the progression of maximal aerobic capacity (VO_2max) across the stages of the Luc Léger Test. VO_2max values increased progressively from 31.1 ml.kg^{-1}.min^{-1} at Stage 3 to 51.3 ml.kg^{-1}.min^{-1} at Stage 10, following the incremental rise in running speed. The distribution of scores indicates that most participants achieved VO_2max values consistent with moderate aerobic fitness levels according to standardized norms.

Presentation and analysis of results related to the second hypothesis

Flexibility (Forward Flexion Test)

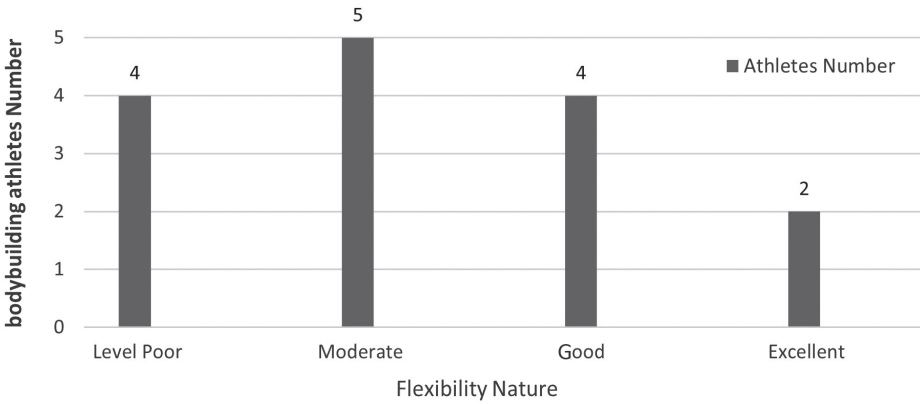

Figure 2 Results of the forward flexion test (Test Flexion Frontal) among a sample of bodybuilding athletes.

Table 3 Results of the forward flexion test (Flexion Frontal Test)

Flexibility	Level poor	Moderate	Good	Excellent
Number of athletes	4	5	4	2

Figure 2 and Table 3 present the distribution of trunk and hamstring flexibility levels obtained from the forward flexion test. The findings show that the highest proportion of athletes fell within the moderate flexibility category (33.3%), followed by poor flexibility (26.7%) and good flexibility (26.7%). Only 13.3% of the sample achieved an excellent level of flexibility.

Overall, flexibility scores among the athletes ranged mainly between poor and moderate levels, with a smaller proportion reaching good or excellent performance.

Shoulder flexibility (Back Scratch Test)

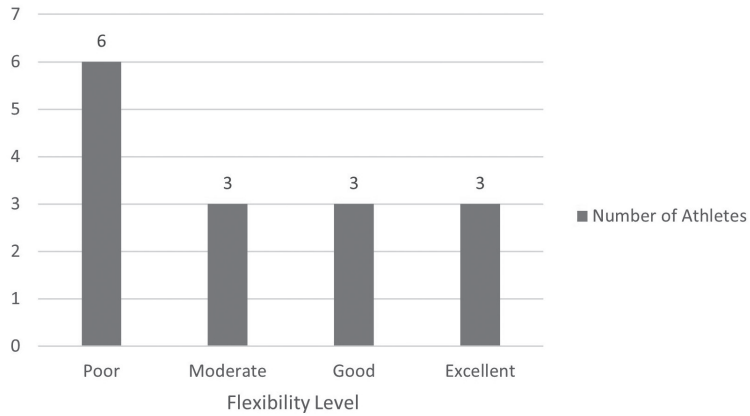

Figure 3 Distribution of flexibility levels in the Back Scratch Test among a sample of bodybuilders.

Table 4 Results of the Back Scratch Test among a sample of bodybuilders

Flexibility level	Poor	Moderate	Good	Excellent
Number of athletes	6	3	3	3

Figure 3 and Table 4 present the distribution of shoulder flexibility levels based on the Back Scratch Test. Most participants demonstrated poor flexibility (40%), while the remaining athletes were distributed equally across the moderate (20%), good (20%), and excellent (20%) categories.

Overall, the majority of the sample fell within the poor flexibility category, indicating generally limited shoulder mobility among the participants.

Presentation and analysis of results related to the third hypothesis

There is a significant correlation between endurance and flexibility with the variables of age and training duration among bodybuilders.

Table 5 Summarizes the correlations between VO_2max, flexibility, age, and training duration

Variables compared	r	p	Relationship	Significance
VO_2max × Age	0.114	0.724	positive	not significant
VO_2max × Training duration	0.056	0.842	positive	not significant
Age × Flexibility	0.484	0.068	positive	not significant
Training duration × Flexibility	0.353	0.197	positive	not significant
Age × Shoulder flexibility	–0.165	0.556	negative	not significant

Table 5 presents the correlation coefficients examining the relationships between aerobic capacity (VO_2max), flexibility, age, and training duration. All correlations were non-significant ($p > 0.05$), indicating that none of the variables showed a statistically measurable association within this sample.

Overall, these findings suggest that age and training duration did not exert a detectable influence on either endurance or flexibility among the participants. Given the small sample size and relative homogeneity of the group, these results should be interpreted cautiously, as limited statistical power may have obscured potential relationships.

More specifically, the correlations between VO_2max and both age ($r = 0.114$, $p = 0.724$) and training duration ($r = 0.056$, $p = 0.842$) were weak and positive, showing no meaningful trend. Similarly, flexibility measures demonstrated non-significant associations with age ($r = 0.484$, $p = 0.068$) and training duration ($r = 0.353$, $p = 0.197$), although the moderate positive correlation with age approached significance and may indicate a potential trend worth exploring in larger samples.

Shoulder flexibility showed a weak, negative non-significant relationship with age ($r = -0.165$, $p = 0.556$), suggesting a slight decline in shoulder mobility with increasing age, though the data do not support a definitive conclusion.

Conclusion

The third hypothesis was not supported. No statistically significant correlations were observed between endurance or flexibility and the variables of age or training duration. Future studies with larger and more diverse samples are recommended to clarify whether meaningful associations may emerge under improved statistical conditions.

DISCUSSION OF RESULTS IN LIGHT OF THE HYPOTHESES

Although the present study did not reveal statistically significant correlations between aerobic capacity, flexibility, age, and training experience, it provides an important contribution to the limited body of research examining these parameters specifically among bodybuilding athletes. Most existing studies focus on strength, hypertrophy, or body composition, while flexibility and endurance remain understudied within this population. By generating descriptive data on multiple physical fitness components and highlighting variability among athletes with similar training backgrounds, this study establishes a baseline for understanding performance characteristics in bodybuilding. The findings also emphasize the need to integrate aerobic and flexibility training into bodybuilding programs, offering practical implications for coaches and practitioners. Furthermore, the absence of significant associations underscores the methodological challenges of small sample research and points to the necessity of larger-scale investigations, thereby helping shape future research directions in this field.

Discussion of the results in light of the first hypothesis

The first hypothesis proposed that bodybuilding athletes would exhibit moderate aerobic capacity. The results of the Luc Léger test support this assumption, as participants demonstrated VO_2max values consistent with the moderate range, reflecting the hypertrophy-oriented nature of bodybuilding training.

Although studies focusing specifically on bodybuilders are limited, previous work confirms the validity of the Luc Léger test and its strong association with directly measured VO_2max in strength-trained individuals (Léger et al., 1988; Campos et al., 2018). Research also shows that aerobic capacity typically declines with age (Hawkins et al., 2001; Fleg & Cooper, 1988) but can be maintained or improved with consistent training and favorable environmental and genetic factors (Bouchard et al., 1999; Léger & Lambert, 1982).

Taken together, these findings confirm the first hypothesis: bodybuilding athletes generally display moderate aerobic capacity compared with endurance athletes. Nevertheless, integrating structured aerobic training may enhance cardiovascular efficiency and improve recovery capacity within bodybuilding programs.

Discussion of the results in light of the second hypothesis

The second hypothesis proposed that bodybuilders would demonstrate limited flexibility. The results of the forward flexion and back-scratch tests support this assumption, as most participants showed poor to moderate flexibility.

Previous research indicates that forward trunk flexion depends on adequate extensibility of the hamstring, lumbar, and hip musculature, as well as neuromuscular regulation and spinal mobility (Anderson et al., 2005; Magnusson & Renström, 2006; Gajdosik & Tippett, 2000; Behm et al., 2016). Strength-training-induced hypertrophy may shorten muscle-tendon units and reduce joint range of motion, especially when stretching is insufficient (Alter, 2004; Worrell & Perrin, 1992). This trend is consistent with findings that bodybuilders often display reduced mobility compared with athletes in sports emphasizing coordination and joint flexibility.

Age-related declines in flexibility are well-documented (Granacher et al., 2018; Santos & Gomes, 2018; Vieira & Gomes, 2020), and similar tendencies were visible in the present sample. Conversely, prior studies indicate that training experience may exert a modest positive influence on flexibility by promoting soft-tissue adaptation (Costa et al., 2018; Santos et al., 2020; Lee & Kim, 2019; Park & Lee, 2020). These findings highlight the importance of integrating regular stretching and mobility exercises into bodybuilding programs to offset hypertrophy-related stiffness and reduce injury risk.

Discussion of the results in light of the third hypothesis

The third hypothesis predicted significant relationships between aerobic capacity, flexibility, age, and training duration. However, none of the correlations in the present study reached statistical significance ($p > 0.05$). This suggests that, within this small and relatively homogeneous sample, age and training duration did not exert measurable influence on VO_2max or flexibility.

The weak positive relationship between VO_2max and age contrasts with long-standing evidence showing age-related declines in aerobic capacity (Fleg & Cooper, 1988; Kemmler & Engelke, 2003; West & Abt, 2017). Meanwhile, the negligible correlation between VO_2max and training duration is inconsistent with studies showing that long-term training can improve cardiovascular efficiency (Léger & Lambert, 1982; Santos & Gomes, 2017; Gomes & Santos, 2018).

Similarly, although flexibility typically decreases with age (Granacher et al., 2018; Santos & Gomes, 2018; Vieira & Gomes, 2020), the moderate near-significant correlation observed in this study ($r = 0.484$) suggests that consistent training may preserve mobility in older athletes. The weak-to-moderate correlation between training duration and flexibility aligns with previous reports indicating positive, though modest, adaptability in connective tissues (Costa et al., 2018; Santos et al., 2020).

Overall, the non-significant results should be interpreted in light of the limited sample size, which may have reduced statistical power and masked meaningful associations. Larger, more diverse samples are needed to clarify the true nature of these relationships in bodybuilding populations.

LIMITATIONS OF THE STUDY

This study presents several limitations that should be considered when interpreting the findings. The most notable limitation is the small sample size ($n = 15$), which substantially reduces statistical power and may have masked meaningful associations between aerobic capacity, flexibility, age, and training experience. The sample was also relatively homogeneous in terms of training background and demographic characteristics, limiting the generalizability of the results to the broader bodybuilding population. Additionally, the study relied on field-based assessments such as the Luc Léger test, forward flexion test, and back-scratch test, which, although valid and widely used, may lack the precision of laboratory-based measurements. The cross-sectional design further restricts the ability to infer causal relationships between training variables and physical fitness outcomes. Future studies would benefit from larger, more diverse samples, longitudinal designs, and the inclusion of laboratory measures to provide a more comprehensive understanding of physiological adaptations in bodybuilding athletes.

CONCLUSION AND RECOMMENDATIONS

This study aimed to examine the relationship between flexibility, endurance, age, and training experience among bodybuilding athletes. Based on the findings obtained from the Luc Léger Test, Forward Flexion Test, and Back Scratch Test, it was concluded that bodybuilding athletes generally demonstrate moderate levels of aerobic capacity and limited flexibility, particularly in the trunk and shoulder regions.

The results revealed that flexibility tends to decline with advancing age but shows a slight improvement with longer training experience, suggesting that consistent engagement in physical activity may partially counteract age-related declines in joint mobility. Conversely, maximal aerobic capacity (VO_2max) was not significantly correlated with either age or training duration, although trends indicated potential improvement with continued training. The absence of statistically significant correlations

is, however, an important finding in itself, indicating that conventional bodybuilding training may not sufficiently stimulate improvements in flexibility or aerobic capacity. These results should be interpreted cautiously due to the limited sample size, which may have reduced statistical power and obscured potential associations.

These findings emphasize the importance of incorporating both flexibility and endurance training into bodybuilding programs. While bodybuilding primarily targets muscular hypertrophy and strength development, neglecting flexibility and aerobic conditioning may lead to muscular imbalances, reduced mobility, and increased injury risk.

Recommendations

1. Coaches and athletes should adopt integrated training approaches that combine resistance training with structured flexibility and aerobic exercises.
2. Flexibility work – such as static and dynamic stretching' – should be included in both warm-up and cool-down phases.
3. Moderate aerobic activities (e.g., interval running, cycling) should be regularly implemented to enhance cardiovascular efficiency and recovery capacity.
4. Future research should include larger and more diverse samples and explore longitudinal designs to better understand the interplay between age, training experience, and physiological adaptation in bodybuilding athletes.

Overall, maintaining a balance between strength, endurance, and flexibility appears essential for optimizing performance, preventing injuries, and sustaining long-term physical health among bodybuilding practitioners.

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