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"Influence of Muscle Hypertrophy on Joint Range of Motion and Flexibility: A Comparative Study of Bodybuilders and Non-Bodybuilders"

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Abstract:
Background: Muscle hypertrophy, a primary outcome of resistance training, is often associated with increased muscle mass and strength; however, its influence on joint range of motion (ROM) and flexibility remains a subject of debate. While hypertrophied muscles may enhance force production, they may also impose mechanical and neuromuscular constraints on joint mobility. Therefore, the present study aimed to investigate the influence of muscle hypertrophy on joint ROM and flexibility by comparing bodybuilders and non-bodybuilders. **Methods:** A comparative research design was employed involving two groups: bodybuilders and non-bodybuilders. Participants were matched for age, height, and body weight to ensure group homogeneity. Anthropometric variables, including age, height, weight, and body mass index (BMI), were recorded. Joint ROM was assessed for hip (flexion, extension, abduction, adduction), knee (flexion and extension), and ankle (dorsiflexion and plantar flexion) using standardized measurement protocols. Independent sample *t*-tests were applied to determine significant differences between groups, with the level of significance set at $p < 0.05$. **Results:** Significant differences in ROM were observed across multiple joint movements. Non-bodybuilders exhibited significantly greater hip flexion (right: 121.30 ± 0.95 vs 117.30 ± 1.70; $t = 6.488$, left: 121.10 ± 0.99 vs 117.50 ± 1.27; $t = 7.060$), hip adduction (right: 21.80 ± 0.63 vs 16.50 ± 1.78; $t = 8.874$, left: 21.90 ± 1.10 vs 16.30 ± 1.42; $t = 9.865$), and left knee flexion (143.80 ± 1.75 vs 138.20 ± 1.87; $t = 6.904$), all statistically significant ($p < 0.05$). Additionally, non-bodybuilders demonstrated superior knee extension (right: 0.08 ± 0.04 vs 0.02 ± 0.04; $t = 3.182$, left: 0.09 ± 0.03 vs 0.02 ± 0.04; $t = 4.20$) and ankle plantar flexion (right: 24.60 ± 0.70 vs 22.60 ± 0.52; $t = 7.27$). Bodybuilders showed significantly higher hip abduction on the right side (45.30 ± 3.02 vs 43.00 ± 1.83; $t = 2.06$, $p < 0.05$). Interestingly, ankle dorsiflexion values showed mixed but significant differences between sides (right: non-bodybuilders higher; left: bodybuilders higher), indicating asymmetrical adaptations. No significant differences were found in hip extension (both sides) and right knee flexion ($p > 0.05$). **Conclusion:** The findings indicate that muscle hypertrophy, as seen in bodybuilders, is associated with reduced joint ROM in several movements, particularly hip flexion, hip adduction, and ankle mobility, suggesting increased muscle stiffness and structural constraints. However, selective improvements, such as in hip abduction, highlight the role of training specificity. These results emphasize that hypertrophy-focused training, if not supplemented with flexibility exercises, may compromise joint mobility. Therefore, integrating structured flexibility training within resistance programs is essential to maintain optimal functional performance and minimize injury risk.

Keywords: Range of Motion, Flexibility, Muscle Hypertrophy, Resistance Training, Physical Fitness.

INTRODUCTION

Flexibility and joint range of motion (ROM) are fundamental components of physical fitness and play a crucial role in athletic performance, movement efficiency, and injury prevention. Flexibility refers to the capacity of a joint or series of joints to move through an unrestricted and pain-free range, influenced by the extensibility of muscles, tendons, ligaments, and joint capsules. Contemporary research suggests that flexibility is not solely a structural attribute but also depends on neuromuscular factors, stretch tolerance, and training adaptations (Behm et al., 2021; Afonso et al., 2021). Moreover, the optimal level of flexibility varies according to sport-specific demands and individual biomechanical characteristics. Resistance training, particularly hypertrophy-oriented training, has gained significant attention for its effectiveness in increasing muscle mass, strength, and overall physical performance. Bodybuilding, a specialized form of resistance training, focuses on the development of muscular size, symmetry, and definition through progressive overload and structured training regimens. While hypertrophy training enhances muscle cross-sectional area and force production, its impact on joint mobility remains controversial. Several studies have suggested that increased muscle mass may impose mechanical restrictions on joint movement, potentially reducing ROM due to increased muscle stiffness and altered muscle architecture (Schoenfeld & Grgic, 2020; Nunes et al., 2020). Conversely, other research indicates that resistance training performed through a full range of motion may maintain or even improve flexibility (Grgic & Schoenfeld, 2022; Warneke et al., 2022).

Body mass index (BMI) is a commonly used anthropometric measure to classify individuals based on body weight relative to height. Although BMI provides a convenient and widely accepted index for population studies, its applicability in athletic populations is often questioned, particularly among individuals with high muscle mass such as bodybuilders. Research has shown that athletes may present elevated BMI values despite having low body fat percentages, thereby limiting the accuracy of BMI as an indicator of adiposity in such populations (Nevill et al., 2021). Nevertheless, BMI remains a useful comparative parameter in sports science research. The relationship between muscle hypertrophy and flexibility has been widely debated in recent literature. While traditional perspectives suggest that hypertrophy may reduce flexibility due to increased muscle stiffness, emerging evidence highlights that flexibility adaptations are multifactorial and depend on training variables such as intensity, volume, and exercise technique (Morton et al., 2021; Androulakis-Korakakis et al., 2024). Furthermore, stretching interventions, long considered essential for improving flexibility, are now understood to primarily enhance stretch tolerance rather than induce permanent structural changes in muscle tissue (Behm et al., 2021; Nakamura et al., 2021). Chronic stretching and resistance training have both been shown to influence muscle-tendon properties, although their effects on ROM may differ depending on the mode of training (Warneke & Keiner, 2023).

Joint range of motion is typically assessed using a goniometer, which provides reliable and objective measurements of angular joint displacement in clinical and sports settings. ROM is influenced by multiple physiological and biomechanical factors, including muscle elasticity, neural regulation, joint structure, and the balance between agonist and antagonist muscle groups. Any imbalance or excessive tightness may predispose individuals to musculoskeletal injuries, while excessive laxity may compromise joint stability (McHugh & Cosgrave, 2021). Therefore, maintaining an optimal balance between strength and flexibility is essential for efficient movement and injury prevention. Despite extensive research on resistance training and flexibility, there remains a lack of consensus regarding the specific effects of muscle hypertrophy on joint ROM, particularly in trained populations such as bodybuilders. Most existing studies have focused on general resistance training rather than hypertrophy-specific adaptations, and limited research has directly compared bodybuilders with non-bodybuilders. Additionally, there is a scarcity of data within the

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Indian context, where variations in training practices, body composition, and lifestyle factors may influence outcomes.

Therefore, the present study was undertaken to examine the influence of muscle hypertrophy on joint range of motion and flexibility by comparing bodybuilders and non-bodybuilders. The findings of this study are expected to contribute to the existing body of knowledge and provide practical implications for coaches, athletes, and sports scientists in designing balanced training programs that optimize both muscular development and joint mobility while minimizing injury risk.

Methodology

3.1 Research Design: The present investigation employed a **comparative research design** to examine the influence of muscle hypertrophy on body mass index (BMI), joint range of motion (ROM), and flexibility variables among bodybuilders and non-bodybuilders. This design facilitated the identification of inter-group differences under controlled and comparable conditions.

3.2 Participants: A total of **twenty (N = 20) male participants** were purposively selected for the study, comprising **ten bodybuilders and ten non-bodybuilders** from Patiala district, Punjab, India. The age of the participants ranged between **18 and 28 years**. All subjects were physically active, medically fit, and free from any musculoskeletal injury or condition that could affect joint mobility. Prior to participation, informed consent was obtained from all subjects, and the study adhered to standard ethical considerations for human research.

3.3 Variables: The study included the following variables:

- **Anthropometric Variable:** Body Mass Index (BMI)
- **Range of Motion Variables:** Hip flexion, extension, abduction, and adduction; knee flexion and extension; ankle dorsiflexion and plantar flexion (both right and left sides)

3.4 Instruments and Equipment: Data were collected using standardized and calibrated instruments:

- Weighing machine (for body weight in kilograms)
- Anthropometric rod/stadiometer (for height in centimeters)
- Universal goniometer (for measuring joint angles in degrees)

3.5 Procedure

Anthropometric Measurements

Height was measured using a stadiometer with participants standing barefoot in an erect posture, ensuring the head was positioned in the Frankfort horizontal plane. Body weight was recorded using a calibrated weighing machine with minimal clothing. Body Mass Index (BMI) was computed using the standard formula:

$BMI = Weight\ (kg) / Height\ (m)^2$

Range of Motion (ROM) Assessment

Joint range of motion (ROM) was assessed using a universal goniometer, following standardized anatomical positioning and measurement protocols to ensure reliability and validity of the data. All measurements were taken for both the right and left sides of the body under controlled conditions. For the assessment of hip flexion and extension, participants were positioned in supine and prone postures respectively, with the fulcrum of the goniometer placed over the greater trochanter, the stationary arm aligned with the lateral midline of the pelvis, and the moving arm aligned with the lateral midline of the

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femur. Hip abduction and adduction were measured in a supine position, with the fulcrum positioned at the anterior superior iliac spine (ASIS), ensuring proper alignment of the goniometer arms along the pelvis and femur while preventing pelvic rotation. For knee flexion and extension, participants were positioned supine, with the fulcrum placed over the lateral epicondyle of the femur, the stationary arm aligned along the femur, and the moving arm along the fibula, ensuring that no rotational movement of the thigh occurred during measurement. Ankle dorsiflexion and plantar flexion were assessed in a seated position with the knee flexed at 90°, minimizing the influence of the gastrocnemius muscle. The fulcrum was aligned with the lateral malleolus, the stationary arm with the fibula, and the moving arm with the fifth metatarsal. During all measurements, particular attention was given to stabilization of adjacent joints and prevention of compensatory movements such as pelvic tilting, limb rotation, or foot inversion/eversion. Each movement was recorded at its maximal voluntary range, and the best value was considered for analysis. These standardized procedures ensured consistency and accuracy in measuring joint mobility across all participants.

3.6 Statistical Analysis: Descriptive statistics, including mean and standard deviation (Mean ± SD), were calculated to summarize the data. An independent samples t-test was applied to determine significant differences between bodybuilders and non-bodybuilders. The level of significance was set at $\boldsymbol{p < 0.05}$. All statistical analyses were performed to examine the influence of muscle hypertrophy on BMI and joint ROM variables.

Results

The present study compared anthropometric characteristics and joint range of motion (ROM) variables between bodybuilders and non-bodybuilders.

TABLE 1: Anthropometric Characteristics of Bodybuilders and Non-Bodybuilders

Variable	Bodybuilders (Mean ± SD)	Non-Bodybuilders (Mean ± SD)	t-value	Significance
Age (years)	23.60 ± 1.57	24.00 ± 1.56	0.571	NS
Height (cm)	174.60 ± 5.29	175.40 ± 3.30	0.405	NS
Weight (kg)	77.50 ± 7.26	77.90 ± 5.85	0.135	NS
BMI (kg/m²)	23.97 ± 0.62	26.22 ± 2.02	3.36*	Significant

*Values are Mean ± Standard Deviation, * = Statistically significant at* $p < 0.05$, *BMI= Body mass Index*

Anthropometric Characteristics: The analysis revealed that there were **no significant differences** between bodybuilders and non-bodybuilders in terms of **age** (23.60 ± 1.57 vs 24.00 ± 1.56 years; t = 0.571), **height** (174.60 ± 5.29 vs 175.40 ± 3.30 cm; t = 0.405), and **body weight** (77.50 ± 7.26 vs 77.90 ± 5.85 kg; t = 0.135), indicating homogeneity between groups. However, a **statistically significant difference** was observed in **Body Mass Index (BMI)**, where non-bodybuilders (26.22 ± 2.02 kg/m²) exhibited significantly higher values compared to bodybuilders (23.97 ± 0.62 kg/m²) (t = 3.36, $p < 0.05$).

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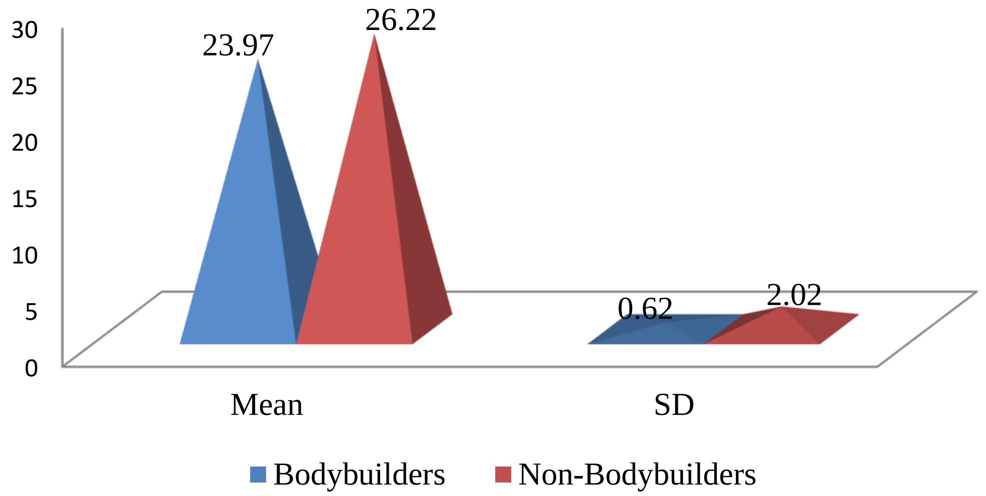

Figure 1: Mean ± Standard Deviation of BMI of Bodybuilders and Non-Bodybuilders

TABLE 2: Comparison of Range of Motion (ROM) Variables Between Groups

Variable	Bodybuilders (Mean ± SD)	Non-Bodybuilders (Mean ± SD)	t-value	Significance
Hip Flexion (Right)	117.30 ± 1.70	121.30 ± 0.95	6.488*	Significant
Hip Flexion (Left)	117.50 ± 1.27	121.10 ± 0.99	7.060*	Significant
Hip Extension (Right)	14.60 ± 1.17	14.10 ± 2.28	0.616	NS
Hip Extension (Left)	14.90 ± 1.10	14.50 ± 2.07	0.539	NS
Hip Abduction (Right)	45.30 ± 3.02	43.00 ± 1.83	2.06*	Significant
Hip Abduction (Left)	45.50 ± 2.99	43.40 ± 2.01	1.842	NS
Hip Adduction (Right)	16.50 ± 1.78	21.80 ± 0.63	8.874*	Significant
Hip Adduction (Left)	16.30 ± 1.42	21.90 ± 1.10	9.865*	Significant
Knee Flexion (Right)	138.50 ± 1.84	138.00 ± 1.63	0.642	NS
Knee Flexion (Left)	138.20 ± 1.87	143.80 ± 1.75	6.904*	Significant
Knee Extension (Right)	0.02 ± 0.04	0.08 ± 0.04	3.182*	Significant
Knee Extension (Left)	0.02 ± 0.04	0.09 ± 0.03	4.20*	Significant
Ankle Dorsi Flexion (Right)	0.28 ± 0.04	0.52 ± 0.06	9.984*	Significant
Ankle Dorsi Flexion (Left)	0.53 ± 0.08	0.28 ± 0.04	8.547*	Significant
Ankle Plantar Flexion (Right)	22.60 ± 0.52	24.60 ± 0.70	7.27*	Significant

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Ankle Plantar Flexion (Left)	24.50 ± 0.85	22.60 ± 0.52	6.042*	Significant

*Values are Mean ± Standard Deviation, * = Statistically significant at**p < 0.05, NS = Not Significant

Range of Motion (ROM) Variables: Significant differences were observed in several ROM variables between the two groups. **Hip Joint:** Non-bodybuilders demonstrated significantly greater hip flexion on both sides (Right: 121.30 ± 0.95 vs 117.30 ± 1.70; t = 6.488, Left: 121.10 ± 0.99 vs 117.50 ± 1.27; t = 7.060; $p < 0.05$). Similarly, hip adduction was significantly higher in non-bodybuilders (Right: 21.80 ± 0.63 vs 16.50 ± 1.78; t = 8.874, Left: 21.90 ± 1.10 vs 16.30 ± 1.42; t = 9.865; $p < 0.05$).

In contrast, bodybuilders showed significantly greater hip abduction on the right side (45.30 ± 3.02 vs 43.00 ± 1.83; t = 2.06, $p < 0.05$). No significant differences were observed in hip extension (both sides) and left hip abduction ($p > 0.05$). **Knee Joint:** Non-bodybuilders exhibited significantly greater left knee flexion (143.80 ± 1.75 vs 138.20 ± 1.87; t = 6.904, $p < 0.05$), while no significant difference was found in right knee flexion (t = 0.642, NS). For knee extension, non-bodybuilders showed significantly higher values on both sides (Right: 0.08 ± 0.04 vs 0.02 ± 0.04; t = 3.182; Left: 0.09 ± 0.03 vs 0.02 ± 0.04; t = 4.20; $p < 0.05$). **Ankle Joint:** Significant differences were observed in ankle dorsiflexion and plantar flexion. Non-bodybuilders demonstrated higher right ankle dorsiflexion (0.52 ± 0.06 vs 0.28 ± 0.04; t = 9.984; $p < 0.05$), whereas bodybuilders showed higher values on the left side (0.53 ± 0.08 vs 0.28 ± 0.04; t = 8.547; $p < 0.05$). For plantar flexion, non-bodybuilders had significantly higher values on the right side (24.60 ± 0.70 vs 22.60 ± 0.52; t = 7.27; $p < 0.05$), while bodybuilders showed higher values on the left side (24.50 ± 0.85 vs 22.60 ± 0.52; t = 6.042; $p < 0.05$). Overall, the results indicate that non-bodybuilders exhibited superior flexibility in most ROM variables, while bodybuilders demonstrated selective advantages in specific movements.

Discussion

The present study aimed to investigate the influence of muscle hypertrophy on joint range of motion and flexibility by comparing bodybuilders and non-bodybuilders. The findings revealed that although both groups were homogeneous in basic anthropometric characteristics, significant differences existed in BMI and multiple ROM variables.

The significantly higher BMI observed in non-bodybuilders may reflect greater fat mass relative to lean mass, whereas bodybuilders, despite having higher muscle mass, demonstrated lower BMI values. This finding supports previous literature suggesting that BMI may not accurately represent body composition in trained individuals due to increased lean muscle mass (Nevill et al., 2021). The results further indicated that non-bodybuilders exhibited significantly greater ROM in key movements such as hip flexion, hip adduction, knee flexion (left), knee extension, and ankle mobility. These findings suggest that individuals not engaged in hypertrophy-focused resistance training may possess greater joint flexibility. This may be attributed to lower muscle stiffness and reduced mechanical restriction around joints. Previous studies have reported that increased muscle hypertrophy may lead to reduced flexibility due to greater passive muscle stiffness and altered muscle architecture (Schoenfeld & Grgic, 2020; Nunes et al., 2020). Conversely, bodybuilders demonstrated significantly greater hip abduction (right side) and mixed results in ankle movements, indicating that resistance training may produce movement-specific adaptations. This aligns with the concept that flexibility adaptations are highly specific to the type and range of movements performed during training (Grgic & Schoenfeld, 2022). Resistance exercises performed through a limited

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range of motion may contribute to restricted flexibility, whereas full-range movements may help maintain or improve joint mobility. The asymmetrical findings observed in ankle dorsiflexion and plantar flexion between sides may be attributed to limb dominance, training patterns, or neuromuscular adaptations. Such asymmetries have been previously reported in athletic populations and may influence movement efficiency and injury risk. Furthermore, the findings support the growing body of evidence that flexibility is influenced not only by structural factors but also by neural adaptations and stretch tolerance (Behm et al., 2021; Nakamura et al., 2021). Bodybuilders, who typically focus on hypertrophy and strength, may not prioritize flexibility training, leading to reduced ROM in certain joints. The absence of significant differences in hip extension and right knee flexion suggests that not all joint movements are negatively affected by hypertrophy, indicating that the relationship between muscle mass and flexibility is complex and multifactorial. Training specificity, exercise selection, and individual biomechanics likely play crucial roles in determining flexibility outcomes (Morton et al., 2021; Androulakis-Korakakis et al., 2024).
Overall, the present findings highlight that while muscle hypertrophy enhances strength and muscular development, it may compromise joint flexibility if not complemented with appropriate stretching and mobility exercises. These results are consistent with previous systematic reviews emphasizing the importance of integrating flexibility training within resistance training programs to optimize performance and reduce injury risk (Afonso et al., 2021; Warneke & Keiner, 2023).

Conclusion

The present study examined the influence of muscle hypertrophy on body mass index (BMI) and joint range of motion (ROM) by comparing bodybuilders and non-bodybuilders. The findings revealed that, although both groups were comparable in age, height, and body weight, a significant difference was observed in BMI, with non-bodybuilders exhibiting higher values. This highlights the limitation of BMI as an indicator of body composition in trained populations, particularly those with higher lean muscle mass. With respect to joint range of motion, non-bodybuilders demonstrated significantly greater flexibility in multiple movements, including hip flexion, hip adduction, knee flexion (left), knee extension, and ankle mobility. These findings suggest that increased muscle hypertrophy may be associated with reduced joint ROM, likely due to factors such as increased muscle stiffness, structural constraints, and reduced emphasis on flexibility training in bodybuilding routines.
However, bodybuilders exhibited superior performance in selected movements, such as hip abduction and certain ankle motions, indicating that resistance training induces movement-specific adaptations rather than a uniform reduction in flexibility. Additionally, the absence of significant differences in some variables (e.g., hip extension and right knee flexion) suggests that the relationship between hypertrophy and flexibility is complex and influenced by training specificity, movement patterns, and neuromuscular factors. In conclusion, while muscle hypertrophy contributes positively to strength and muscular development, it may adversely affect joint mobility if not accompanied by adequate flexibility training. Therefore, a balanced training approach integrating both resistance and flexibility exercises is essential for optimal functional performance and injury prevention.

Practical Implications

The findings of this study have several important implications for athletes, coaches, fitness professionals, and sports scientists:

- **Integration of Flexibility Training:** Resistance training programs, particularly those focused on hypertrophy, should incorporate structured flexibility exercises (e.g., static stretching, dynamic mobility drills) to maintain or improve joint ROM and prevent stiffness.

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- **Injury Prevention Strategies:** Reduced flexibility in hypertrophied muscles may increase the risk of muscle strains, joint restrictions, and movement inefficiencies. Therefore, regular ROM assessments and corrective exercises should be included in training protocols. .
- **Balanced Development Approach:** Coaches and trainers should emphasize a holistic approach that balances strength, hypertrophy, flexibility, and mobility to enhance overall athletic performance.
- **Addressing Asymmetries:** Observed side-to-side differences in ROM highlight the importance of identifying and correcting muscular imbalances through unilateral training and targeted mobility interventions.
- **Program Periodization:** Incorporating flexibility-focused phases within resistance training cycles may help mitigate the negative effects of hypertrophy on joint mobility.

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