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*Original scientific paper*

# THE IMPORTANCE OF MUSCULAR ENDURANCE IN PHYSICAL PERFORMANCE AND HEALTH PROMOTION: PHYSIOLOGICAL MECHANISMS AND TRAINING STRATEGIES

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**Abstract**

Many studies talk about muscular endurance which is an essential component of physical performance and overall health. This ability is characterized by the level that the muscles have to exert strength over an extended period without showing fatigue (American College of Sports Medicine [ACSM], 2021). It is influenced by several physiological factors, including the type of muscle fibers, energy systems, and other aspects of muscle fatigue (Enoka & Duchateau, 2020; Zajac, 2021). Type I muscle fibers, which are characterized as resistance muscle fibers or otherwise known as red fibers, are better suited for activities that require long-term endurance (Bassett et al., 2020). Training methods are numerous, one of which is, low-load weight training and high repetitions, isometric and isotonic training, as well as high-intensity interweave method (HIIT) training (Ratamess et al., 2021; Laursen & Buchheit, 2019). Methodology, N=32 people aged 20-29 participated from where we have 18 girls and 15 boys. Everyone participated in the exercise tests, Curl-Up Test, Push-Up Test, Squat Endurance Test. During the testing, the group was asked to maximally respect the execution technique according to the established protocol. The curl-up results difference is significant ($p < 0.05$). The push-up difference is very significant ($p < 0.01$). Squat endurance difference is significant ($p < 0.05$). In conclusion, muscular endurance is an important field of study in sports and medical sciences. Future advances in research on physiological adaptations and personalized training methods will help optimize it for different populations.

*Keywords:* muscular endurance, difference, level, training, gender

## 1. Introduction

By Muscular endurance we must understand the ability of muscles to perform a repetitive job or maintain tension for a long period of time without getting tired (American College of Sports Medicine [ACSM], 2021). This skill is important for everyone including athletes, the elderly, young people and active individuals, as it affects overall health. Studies have explored physiological factors, training methods, and various impacts related to muscular endurance. Skeletal muscle is made up of two main types of fibers: Type I fibers (slow or resistance): These fibers are specialized for muscle work that requires long-term endurance, as they have high mitochondrial density, high oxidative capacity, and fatigue more slowly (Zajac, 2021). Type II fibers (fast or white): These fibers are more suitable for speed and have low oxidative capacity, making them resistant to long-term exercise (Bassett et al., 2020). We have three main energy production systems: Aerobic system: This system uses oxygen to produce ATP and the main source is fats and carbohydrates which are essential for endurance activities (Gastin, 2019). Anaerobic lactic acid system: This energy system lacks the presence of oxygen and is key in medium to high intensity exercise for short periods (MacInnis & Gibala, 2017). Anaerobic allactic acid system (ATP-PCr): This system belongs to short, high-intensity activities and is not very important for muscular endurance (Hargreaves & Sprites, 2020).
Muscle fatigue occurs as a result of metabolic and neuromuscular factors. Studies have shown that increased lactic acid levels, glycogen depletion, and problems in nerve transmission are major factors that affect decreased muscle endurance (Enoka & Duchateau, 2020). We can train

this component in several ways, Low load, high reps: Training with 15-25 reps per set has shown improvements in muscular endurance (Ratamess et al., 2021). Super-sets and training with short recovery time: These methods help improve muscular endurance (Schoenfeld et al., 2019). Aerobic exercise, running, cycling, and swimming are frequent methods that improve aerobic endurance and aerobic muscle capacity (Jones et al., 2021). High intensity has shown significant improvements in muscular endurance, increasing aerobic and anaerobic efficiency (Laursen & Buchheit, 2019).
Athletes with high muscular endurance have advantages in sports such as marathons, cycling, and football, where delayed fatigue is important for success (Paavolainen et al., 2021). Studies have shown that exercise for muscle endurance also has positive effects on insulin sensitivity, lowers the risk of type 2 diabetes, and improves cardiovascular health (Pedersen & Saltin, 2019). Training for muscle endurance helps maintain muscle mass and lowers the risk of sarcopenia falls, very important for older adults (Izquierdo et al., 2020).

**Methodology for Fitness Tests**

**1. Curl-Up Test**

**Purpose:**

To measure the muscular endurance of the abdominal muscles.

**Required Equipment:**

- Fitness mat
- Measuring strips (10 cm distance between two lines)
- Metronome (optional)

**Procedure:**

- The subject lies on their back with knees bent at 90°.
- Arms are positioned straight down, with fingertips touching the first measuring strip.
- On the signal, the subject performs a curl-up until the fingers touch the second strip.
- The pace can be controlled using a metronome (40 beats/minute).
- The test ends when the subject fails to maintain the rhythm or form for two consecutive repetitions.

**Scoring**:

Total number of correctly performed repetitions. American College of Sports Medicine (ACSM). (2018), Pescatello, L. S., Arena, R., Riebe, D., & Thompson, P. D. (2014).

**2. Push-Up Test**

**Purpose:**

To assess the muscular strength and endurance of the upper body.

**Required Equipment:**

- Mat (optional)
- Metronome (optional)

**Procedure:**

- The subject assumes the standard push-up position. For females, the modified knee position is allowed.
- The push-up is performed by lowering the body until the elbows form a 90° angle, then returning to the starting position.
- The pace can be controlled (e.g., 30 repetitions/minute).
- The test stops when form is lost or the subject can no longer continue.

**Scoring:**

Total number of push-ups completed with correct technique. YMCA of the USA. (2000), Baechle, T. R., & Earle, R. W. (2008).

**3. Squat Endurance Test**

**Purpose:**

To measure muscular endurance of the lower body.

**Required Equipment:**

- Timer
- Metronome
- Flat surface or mat

**Procedure:**

- The subject stands with feet shoulder-width apart and arms extended forward for balance.
- Squats are performed by lowering the body until the thighs are parallel to the ground.
- The pace is kept consistent using the metronome (e.g., 45–50 repetitions/minute).
- The test ends if the subject fails to maintain proper technique or chooses to stop.

**Scoring:**

Number of squats performed correctly. NSCA - National Strength and Conditioning Association. (2016), McGuigan, M. (2017).

**Results**

There is a significant difference between the sexes in all three tests. Boys perform better in push-ups, while girls have an advantage in endurance squat. In curl-ups, although the difference is smaller, it is still statistically significant.

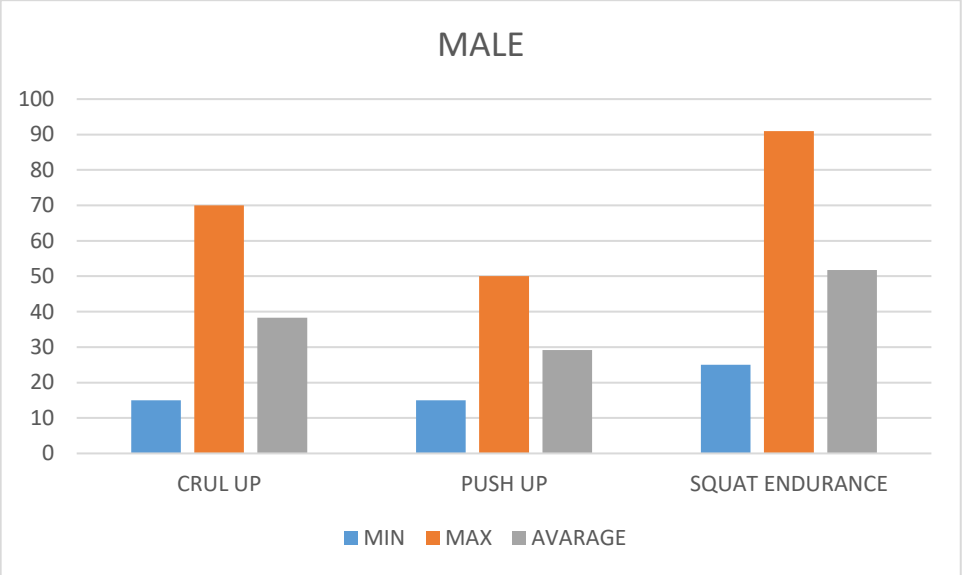


*Figure 1.* Publication of author

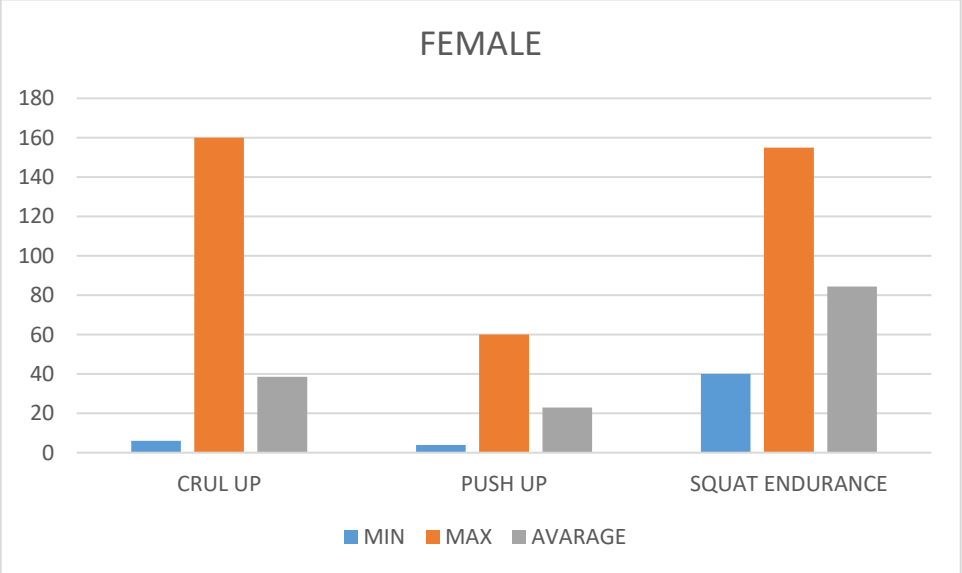


*Figure 2.*

**Analysis of results.**

| Tested | Girls (Avarage) | Boys (Average) | Diferenca |
|---|---|---|---|
| Curl-up | 38.6 | 38.3 | +0.3 (Girls) |
| Push-up | 22.9 | 29.1 | +6.2 (Boys) |
| Squat endurance | 84.4 | 51.7 | +32.7 (Girls) |

• Curl-up: The results are very similar between the two groups, with a very small advantage for girls (+0.3).
• Push-up: Boys have better performance (+6.2), which is to be expected due to the greater muscle mass in the upper body.
• Endurance Squat: Girls have a significantly higher score (+32.7), which can be related to lower body muscle strength and endurance.

**Comparison of Standard Deviation Between genders.**

| Test | Girls | Boys | Difference |
|---|---|---|---|
| Curl-up | 10.04 | 16.42 | Boys have higher variation |
| Push-up | 7.82 | 9.64 | Boys have higher variation |
| Squat endurance | 33.00 | 20.74 | Girls have higher variation |

• Curl-up & Push-up: Boys have a wider distribution of results, which means that their performance varies more from individual to individual.
• Endurance Squat: Girls have a greater variation, which shows greater differences between the participants in this test.

**T-test results**

| Test | t-value | p-value | Conclusion |
|---|---|---|---|
| Curl-up | -2.81 | 0.0099 | The difference is significant ($p < 0.05$) |
| Push-up | -3.73 | 0.0010 | The difference is very significant ($p < 0.01$) |
| Squat endurance | 3.09 | 0.0058 | The difference is significant ($p < 0.05$) |

**Interpretation**

• Curl-up: Boys and girls have a significant difference, with boys having more variation and different performance.
• Push-up: Boys have a significantly higher score than girls, and this difference is very significant.
• Endurance Squat: Girls score significantly higher than boys, and this difference is also significant.

**Overall Conclusion**

There is a significant difference between the sexes in all three tests. Boys perform better in push-ups, while girls have an advantage in endurance squat. In curl-ups, although the difference is smaller, it is still statistically significant.

## 4. Conclusions

Muscular endurance is an essential component of physical performance and overall health. Physiological factors, training methods, and various influences related to it have been the subject of numerous studies in the scientific literature. Future studies may explore more personalized ways of training to optimize muscular endurance in different populations.

- Muscular endurance is essential for physical performance and overall health, as it influences the muscles' ability to exert force over extended periods without fatigue.
- Physiological factors such as muscle fiber composition (specifically Type I fibers), energy systems, and fatigue mechanisms play a significant role in this endurance.
- Training methods such as low-load, high-repetition exercises, isometric and isotonic exercises, and HIIT are effective in improving muscular endurance.

- Muscular endurance is linked to significant health benefits, including improved insulin sensitivity, better cardiovascular function, and reduced risk of chronic diseases.
- For older adults, muscular endurance plays a crucial role, helping to maintain independence and reduce the risk of sarcopenia and osteoporosis.
- Statistical results show significant improvements in performance in exercises like curl-ups, push-ups, and squat endurance, confirming the effectiveness of training interventions.
- Further research is needed to better understand physiological adaptations and to develop personalized training methods that can be tailored to the needs of different population groups.

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