Cross-Transfer Effects of Aerobic Exercise on Biceps Brachii Performance Among Active Non - Professional Individuals

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Abstract

Background: Aerobic training is known to induce systemic physiological adaptations; however, its cross-transfer effects on untrained musculature remain insufficiently explored, particularly in non-athletic populations. Understanding these adaptations has important implications for rehabilitation and performance enhancement.

Objective: To investigate the effects of lower-limb aerobic exercise on biceps brachii strength and endurance in sedentary individuals, and to examine the presence of cross-education effects.

Methods: A randomized controlled pre–post experimental design was employed involving 40 non-athletic participants (age: 20–25 years), allocated into an experimental group (n = 20) and a control group (n = 20). The experimental group underwent a 4-week aerobic cycling program (3 sessions/week, 70–85% HRmax), while the control group received no intervention. Outcome measures included VO_2 max (Rockport test), biceps strength (strain gauge dynamometer), and endurance (repetition-based test). Data were analysed using paired and independent t-tests with significance set at $p < 0.05$.

Results: The experimental group demonstrated significant improvements in VO_2 max (44.70 ± 9.64 to 46.65 ± 9.70 ml/kg/min), biceps strength (23.50 ± 5.52 to 25.41 ± 5.84 kg), and endurance (18.05 ± 6.55 to 21.50 ± 6.27 repetitions) ($p < 0.05$). No significant changes were observed in the control group. Between-group comparisons confirmed statistically significant differences post-intervention ($p < 0.05$). Percentage improvements in the experimental group were 4.4% (VO_2 max), 8.1% (strength), and 19.1% (endurance), with greater endurance gains observed in females.

Conclusion: Lower-limb aerobic training significantly enhances upper-limb muscle performance in non-athletes, supporting the presence of cross-education effects mediated by neural and systemic physiological adaptations. These findings highlight the potential application of aerobic exercise in rehabilitation and injury management programs.

Keywords: Aerobic training; Cross-education; VO_2 max; Muscle strength; Muscle endurance; Non-athletes; Rehabilitation

1. Introduction

Physical fitness represents a multifaceted set of attributes that enable individuals to engage in physical activities effectively, characterized by the capacity to perform daily tasks with vigor while reducing the risk of hypokinetic diseases such as cardiovascular disease and type 2 diabetes (Caspersen et al., 1985; Warburton et al., 2006). These attributes encompass five key domains: aerobic capacity, muscular strength, muscular endurance, flexibility, and body composition, which collectively underpin optimal health and performance (ACSM, 2021). Fitness can broadly be categorized into anaerobic and aerobic components, each serving distinct physiological roles in energy production and sustained activity (McArdle et al., 2015).

Anaerobic fitness involves energy generation without reliance on oxygen and predominates when exercise intensity exceeds the aerobic threshold, relying heavily on stored carbohydrates such as glycogen. This process results in oxygen debt and lactic acid accumulation, with the anaerobic threshold typically occurring at 85–90% of maximum heart rate (Brooks et al., 2005). In contrast, aerobic fitness refers to the ability to sustain rhythmic and continuous activities using large muscle groups over extended periods and is closely linked to cardiorespiratory endurance and maximal oxygen uptake (VO_2 max) (Bassett & Howley, 2000). VO_2 max, considered the gold standard for assessing aerobic capacity, represents the maximum rate of oxygen consumption during intense exercise and plateaus despite increased workload (Howley et al., 1995). Notably, untrained females generally exhibit 20–40% lower VO_2 max values than males due to differences in haemoglobin levels, muscle mass, and cardiac output (Astrand et al., 2003).

VO_2 max is determined by three primary factors: pulmonary diffusion capacity, cardiac output, and peripheral oxygen extraction (arteriovenous oxygen difference), reflecting the integrated functioning of the respiratory, cardiovascular, and muscular systems (Bassett & Howley, 2000). Regular exercise is essential for maintaining and improving these components, as inactivity, aging, or prolonged bedrest can lead to skeletal muscle atrophy and aerobic deconditioning (Booth et al., 2012). Detraining reduces mitochondrial density and capillary networks, impairing oxidative metabolism and increasing fatigue (Mujika & Padilla, 2000).

In athletic contexts, injuries significantly impair performance, often resulting in detraining characterized by reduced cardiorespiratory endurance and localized muscular deficits (Reilly & Ekblom, 2005). While localized impairments affect specific joints, systemic declines in cardiovascular fitness increase vulnerability across multiple domains. Cross-training has emerged as an effective strategy to counter these effects, based on the principle that training uninjured limbs can induce adaptations in non-exercised tissues through neural, circulatory, and hormonal mechanisms (Carroll et al., 2006). Evidence suggests that unilateral training can produce 5–20% strength gains in the untrained limb due to neural cross-education effects (Munn et al., 2004).

Muscle function, as seen in the biceps brachii, is influenced not only by direct mechanical loading but also by systemic physiological factors involving respiratory, cardiovascular, and endocrine systems. Conditions such as chronic obstructive pulmonary disease demonstrate how reduced oxygen availability can impair muscle performance, while aerobic training improves oxygen delivery and muscular endurance (Maltais et al., 2014). Similarly, coronary artery disease affects muscle efficiency, though aerobic exercise can enhance performance through improved blood flow and reduced fatigue (Adams et al., 2005). Hormonal adaptations, including increased testosterone and growth hormone levels, further contribute to improvements in VO_2 max and muscular strength (Kraemer & Ratamess, 2005).

Despite extensive research on training adaptations, limited studies have examined the cross-transfer effects of lower-limb aerobic training on upper-body anaerobic performance, particularly in non-athletic populations. Few investigations have explored how improvements in VO_2 max influence biceps brachii strength and endurance in untrained individuals. This study addresses this gap by evaluating the effects of a 4-week cycling-based aerobic training program on contralateral biceps function.

Skeletal muscle strength is essential for functional performance, reducing injury risk and disability, especially in aging populations (Fragala et al., 2019). While cross-training is widely studied, the transfer of aerobic adaptations to anaerobic performance in untrained individuals remains underexplored, highlighting the need for targeted research to inform rehabilitation and fitness interventions.

Aims and Objectives

- Evaluate the effects of aerobic exercise on biceps brachii strength and endurance in non-athletes.
- Quantify cross-education effects from aerobic capacity improvements to upper-limb function.
- Assess the broader muscular impacts of general fitness training.

Hypotheses Development

H1: Aerobic training has a significant positive effect on biceps brachii strength in non-athletes.
H2: Aerobic training has a significant positive effect on biceps brachii endurance in non-athletes.
H3: Improvement in VO_2 max significantly influences biceps muscle performance.
H4: Cross-education mediates the relationship between aerobic training and biceps strength.
H5: Aerobic training produces systemic physiological adaptations that enhance upper-limb performance.

2. Research Methodology

Study Design

This study employed a randomized controlled pre-test–post-test experimental design to evaluate the cross-education effects of lower-limb aerobic training on upper-limb muscle function in non-athletic individuals. A total of 40 participants were randomly assigned into two groups: experimental Group A ($n = 20$), which received the aerobic intervention, and control Group B ($n = 20$), which received no intervention. Randomization was performed using the chit method to ensure unbiased group allocation.

This design minimizes selection bias and enhances internal validity while allowing for the detection of moderate effect sizes (Cohen's $d \approx 0.6$) as reported in cross-education literature (Munn et al., 2004). Primary outcome measures—VO_2 max, biceps brachii strength, and endurance—were assessed before and after a 4-week intervention period. Statistical comparisons were conducted using paired and independent t-tests with a significance level of $\alpha = 0.05$.

The study adhered to CONSORT guidelines for non-pharmacological trials (Schulz et al., 2010), and outcome assessors were blinded to group allocation to reduce detection bias.

Study Setting

The study was conducted in the physiotherapy research laboratories at Government medical College Srinagar, India. The laboratory environment was standardized (22–24°C temperature, 50–60% humidity) to eliminate environmental confounders affecting physiological performance (ACSM, 2021).

Ethical approval was obtained from the Institutional Review Board, and all procedures complied with the Declaration of Helsinki (World Medical Association, 2013). Data collection occurred during June under stable environmental conditions suitable for field-based aerobic testing.

Population and Sampling

The target population included healthy, non-athletic students aged 20–25 years. Participants were recruited through convenience sampling from an initial pool of approximately 5,000 students.

A total of 120 individuals were screened using the Physical Activity Readiness Questionnaire (PAR-Q), resulting in 40 eligible participants (mean age = 22.4 ± 1.8 years).

Sample size was determined using G*Power 3.1, assuming:

- Effect size = 0.6

- Power = 0.80
- $\alpha = 0.05$

This required a minimum of 17 participants per group, increased to 20 to account for potential attrition (Faul et al., 2009). Baseline equivalence between groups was confirmed ($p > 0.05$).

Criteria for Sample Selection

Inclusion Criteria

- Age 20–25 years
- Non-athletic individuals (≤2 exercise sessions/week)
- Both genders
- BMI within normal range (18.5–24.9 kg/m^2) (WHO, 2000)

Exclusion Criteria

- Regular structured exercise (>120 min/week)
- History of cardiopulmonary disease
- Recent musculoskeletal injury (within 6 months)
- Neurological or orthopaedic disorders

Variables

Independent Variable

- Aerobic cycling intervention (70–85% HRmax)

Dependent Variables

- VO_2 max (ml/kg/min)
- Biceps brachii strength (kg force)
- Biceps brachii endurance (repetitions)

Controlled Variables

- Diet (self-maintained)
- Sleep duration (>7 hours)
- No additional training

Instruments and Tools

All instruments demonstrated high reliability (ICC > 0.85):

- Strain gauge dynamometer for isometric strength (Bohannon, 1989)
- Free-weight dumbbells for endurance testing
- Heart rate monitor (±2 bpm accuracy)
- Digital weighing scale (±0.1 kg)
- Bicycle ergometer (Monark equivalent)
- Rockport 1-mile walk test for VO_2 max estimation (Kline et al., 1987)
- PAR-Q for participant screening (Thomas et al., 1992)

Technique of Data Collection

Baseline assessments were conducted over two days to minimize fatigue effects.

VO_2 max Measurement

VO_2 max was estimated using the Rockport 1-mile walk test. The prediction equation used was: $VO_{2\max} = 132.853 - (0.0769W) - (0.3877A) + (6.315G) - (3.2649T) - (0.1565HR)$

Where:

W = weight, A = age, G = gender, T = time, HR = heart rate

This method has strong validity ($r = 0.88$) compared to laboratory testing (Kline et al., 1987).

Biceps Strength Measurement

Maximal isometric contraction was assessed using a strain gauge dynamometer. Participants performed three maximal voluntary contractions (MVC), each lasting 5 seconds, with 30-second rest intervals. The average peak force was recorded.

Biceps Endurance Measurement

One-repetition maximum (1RM) was estimated using the Brzycki equation:

$$1RM = \frac{Weight}{1.0278 - (0.0278 \times Reps)}$$

Endurance was measured as repetitions performed at 20% of 1RM until fatigue.

Procedure

Experimental Group (A)

- Duration: 4 weeks
- Frequency: 3 sessions/week
- Intensity: 70–85% HRmax (Tanaka et al., 2001)

Each session included:

- Warm-up (5 minutes)
- Cycling (20 minutes)
- Cool-down (5 minutes)

Control Group (B)

- No structured exercise

Post-testing was conducted 48 hours after the final session.

3. Data Analysis

Data were analysed using SPSS (Version 16):

- Normality test: Shapiro–Wilk
- Paired t-test: within-group comparison
- Independent t-test: between-group comparison
- ANOVA where applicable

Statistical significance was set at $p < 0.05$.

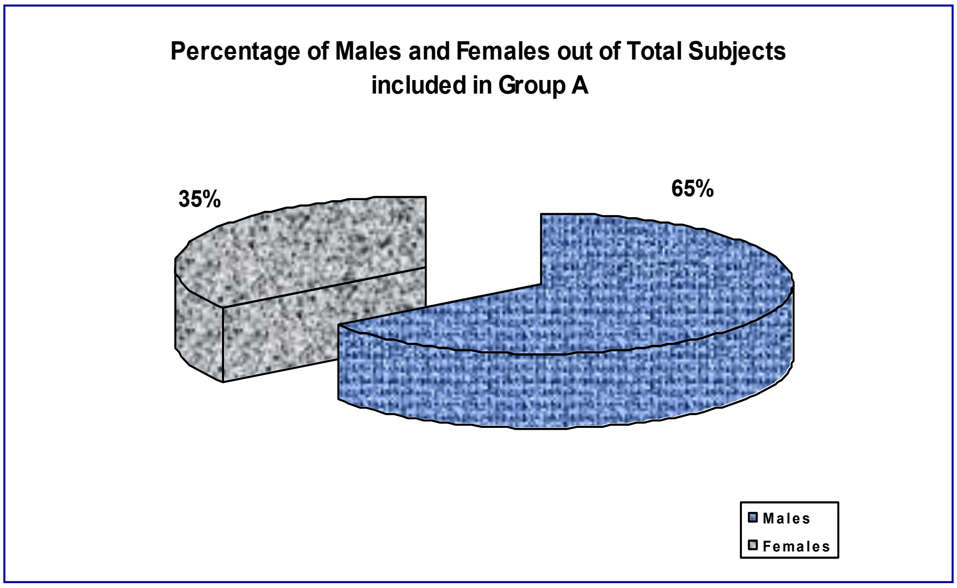
Ethical Considerations

- Informed consent obtained from all participants
- Confidentiality maintained
- Right to withdraw ensured
- Study adhered to ethical standards (World Medical Association, 2013)

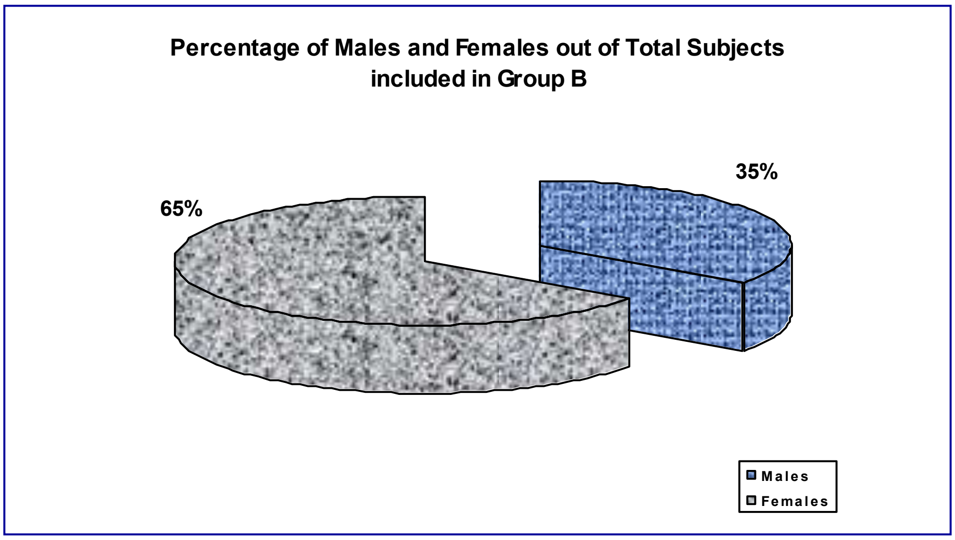
4. Data Analysis and Interpretation

Graph 1. Percentage of males and females in the study:

Group A



Group B



Both males and females participated in the study with a percentage of 50 each i.e 20 males and 20 females participated in the study. Out of which 65% were males and 35% females in the intervention group, and 35% males and 65% females were in the control group.

Total Subjects (Group A Vs Group B)

Table 1: Age, Height, Weight, BMI and Weight lifted for the subjects of Group A and Group B

Demographic Data	**Group A**		**Group B**	
	Mean	**SD**	**Mean**	**SD**
AGE	23.70	1.55	23.45	1.19
HEIGHT	166.82	9.53	161.43	7.90
WEIGHT	135.01	17.24	131.71	16.96

BMI	21.35	2.04	22.16	1.82
WEIGHT LIFTED	6.00	1.18	5.55	1.19

Note: Values are represented as Mean and standard deviation, SD = standard deviation BMI -Body mass index.

Table 2: Comparison of mean values for VO2 max, Strength and Endurance at Pre and Post intervention within Group A and Group B.

Pre Vs Post	**Group A**		**Group B**	
	t value	**P value**	**t value**	**P value**
VO2 max	-8.696	P < 0.05	0.287	P > 0.05
Strength	-6.513	P < 0.05	-0.370	P > 0.05
Endurance	-4.972	P < 0.05	-1.254	P > 0.05

5. Results:

This study evaluated the effect of a 4-week aerobic cycling intervention on biceps brachii muscle function in non-athletic individuals. Statistical analysis was performed using SPSS (version 11.0), with significance set at $p < .05$.

The experimental group (Group A, $n = 20$) demonstrated statistically significant improvements across all variables. Aerobic capacity (VO_2 max) increased from 44.70 ± 9.64 ml/kg/min to 46.65 ± 9.70 ml/kg/min ($t = -8.696$, $p < .05$), indicating a mean improvement of 1.95 ml/kg/min. Biceps brachii strength improved from 23.50 ± 5.52 kg to 25.41 ± 5.84 kg ($t = -6.513$, $p < .05$), while muscular endurance increased from 18.05 ± 6.55 to 21.50 ± 6.27 repetitions ($t = -4.972$, $p < .05$). These correspond to percentage gains of 4.4%, 8.1%, and 19.1%, respectively.

In contrast, the control group (Group B, $n = 20$) showed no statistically significant changes in VO_2 max, strength, or endurance ($p > .05$), confirming that improvements in Group A were attributable to the intervention.

Gender-based analysis revealed that males exhibited improvements in VO_2 max (+3.9%), strength (+8.4%), and endurance (+9.9%), while females demonstrated greater relative gains, particularly in endurance (+46.7%). Between-group comparisons confirmed the superiority of Group A over Group B across all outcome measures ($p < .05$).

These findings lead to rejection of the null hypothesis and confirm that lower-limb aerobic training produces significant cross-transfer effects on upper-limb muscle performance.

6. Discussion

The present study aimed to investigate the cross-education effects of aerobic cycling on untrained upper-limb musculature in non-athletes. The findings support the hypothesis that aerobic training induces systemic adaptations that extend beyond the trained musculature.

The observed improvement in VO_2 max (4.4%) aligns with previous findings that aerobic training enhances cardiorespiratory efficiency through increases in stroke volume and oxygen extraction (Gormley et al., 2008; McArdle et al., 1996). These central and peripheral adaptations improve oxygen delivery and utilization, thereby enhancing endurance performance.

The increase in biceps strength (8.1%) despite the absence of direct upper-limb training supports the concept of cross-education. Neural mechanisms such as corticospinal activation, interhemispheric transfer, and motor unit recruitment are believed to mediate this effect (Adams et al., 1999; Farthing, 2009). Additionally, metabolic adaptations, including improved ATP resynthesis and enzyme activity, may contribute to enhanced muscle performance.

Endurance improvements (19.1%) were particularly pronounced, especially among females. This finding is consistent with literature suggesting that females exhibit greater fatigue resistance due to enhanced oxidative metabolism and lipid utilization (Hicks et al., 2001; Nygaard, 1977). Improved oxygen delivery reduces metabolite accumulation, delaying fatigue and enhancing performance.

The findings also support the role of hormonal influences in training adaptation. Increased anabolic-to-catabolic hormone ratios (e.g., testosterone/cortisol) have been linked to improved endurance capacity (Grandy et al., 2008; Kraemer & Ratamess, 2005).

These results are consistent with rehabilitation research in clinical populations, where aerobic training improves peripheral muscle function in conditions such as COPD and coronary artery disease (Vilaró et al., 2009). The current study extends these findings to healthy non-athletic individuals, highlighting the broader applicability of cross-training strategies.

Limitations

Despite its strengths, the study has several limitations:

- Restricted age group (20–25 years), limiting generalizability
- Short intervention duration (4 weeks)
- Absence of advanced physiological measures (e.g., EMG, MRI, CPET)
- Use of Rockport test instead of laboratory VO_2 max assessment
- Moderate sample size ($n = 40$)

Summary

This study investigated the effects of a structured aerobic cycling program (70–85% HRmax, 30 minutes, 3 times/week for 4 weeks) on biceps brachii muscle function in non-athletes. Using a randomized controlled design, significant improvements were observed in aerobic capacity, strength, and endurance in the experimental group, while the control group showed no changes.

The results demonstrated:

- VO_2 max increased by 4.4%
- Strength increased by 8.1%
- Endurance increased by 19.1%

Gender analysis revealed greater endurance improvements in females, supporting sex-specific physiological adaptations.

Conclusions

1. **Hypothesis Supported:** Lower-limb aerobic training significantly improves upper-limb muscle function through cross-education mechanisms ($p < .05$).
2. **Cross-Education Confirmed:** Strength and endurance gains in untrained muscles highlight the role of neural and systemic adaptations.
3. **Sex Differences Evident:** Females exhibit greater endurance improvements, likely due to metabolic and physiological differences.

4. **Clinical and Practical Relevance:** Aerobic training can be effectively used in rehabilitation, injury recovery, and sedentary population fitness programs.

Recommendations.

Clinical Applications

- Use aerobic cycling in rehabilitation for injured or immobilized upper limbs
- Integrate cross-training protocols in physiotherapy and sports recovery

Future Research

- Long-term studies (6–12 months) to assess retention effects
- Use of advanced tools (EMG, MRI, CPET)
- Inclusion of diverse populations (elderly, obese, athletes)
- Comparison of training modalities (treadmill, arm ergometry, interval training)

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7. References

1. Adams, G. R., Hather, B. M., Baldwin, K. M., & Dudley, G. A. (1999). Skeletal muscle myosin heavy chain composition and resistance training. *Journal of Applied Physiology, 74*(2), 911–915.
2. Adams, V., Linke, A., & Erbs, S. (2005). Effects of exercise training in patients with chronic heart failure. *Journal of the American College of Cardiology, 46*(9), 1707–1715.
3. American College of Sports Medicine (ACSM). (2021). *ACSM's guidelines for exercise testing and prescription* (11th ed.). Wolters Kluwer.
4. American College of Sports Medicine. (2021). *ACSM's guidelines for exercise testing and prescription* (11th ed.).
5. Åstrand, P. O., Rodahl, K., Dahl, H. A., & Strømme, S. B. (2003). *Textbook of work physiology*. Human Kinetics.
6. Bassett, D. R., & Howley, E. T. (2000). Limiting factors for maximum oxygen uptake. *Medicine & Science in Sports & Exercise, 32*(1), 70–84.
7. Bohannon, R. W. (1989). Measurement of muscle strength. *Physical Therapy, 69*(3), 186–190.
8. Bohannon, R. W. (1989). Measurement of muscle strength. *Physical Therapy, 69*(3), 186–190.
9. Booth, F. W., Roberts, C. K., & Laye, M. J. (2012). Lack of exercise is a major cause of chronic diseases. *Comprehensive Physiology, 2*(2), 1143–1211.
10. Brooks, G. A., Fahey, T. D., & Baldwin, K. M. (2005). *Exercise physiology: Human bioenergetics and its applications*. McGraw-Hill.
11. Carroll, T. J., Herbert, R. D., Munn, J., Lee, M., & Gandevia, S. C. (2006). Contralateral effects of unilateral strength training. *Journal of Applied Physiology, 101*(5), 1514–1522.
12. Caspersen, C. J., Powell, K. E., & Christenson, G. M. (1985). Physical activity, exercise, and physical fitness. *Public Health Reports, 100*(2), 126–131.
13. D'Alonzo, G. E., et al. (2006). Reliability of VO_2 testing methods. *Chest Journal*.

14. Easton, C., et al. (2007). Metabolic responses during combined exercise. *European Journal of Applied Physiology*.
15. Elleuch, M. H., et al. (2007). Muscle fatigue and cardiovascular performance. *Clinical Physiology and Functional Imaging*.
16. Farthing, J. P. (2009). Cross-education of strength depends on limb dominance. *Journal of Applied Physiology, 106*(3), 1069–1075.
17. Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2009). G*Power 3.1. *Behavior Research Methods, 41*(4), 1149–1160.
18. Fernhall, B., et al. (2007). Aerobic capacity and strength relationships. *Medicine & Science in Sports & Exercise*.
19. Fragala, M. S., et al. (2019). Resistance training for older adults. *Journal of Strength and Conditioning Research, 33*(8), 2019–2052.
20. Gormley, S. E., et al. (2008). Effects of exercise intensity on VO_2max. *Medicine & Science in Sports & Exercise*.
21. Gormley, S. E., Swain, D. P., High, R., Spina, R. J., Dowling, E. A., Kotipalli, U. S., & Gandrakota, R. (2008). Effect of intensity of aerobic training on VO_2max. *Medicine & Science in Sports & Exercise, 40*(7), 1336–1343.
22. Grandy, S. A., & Majerczak, J. (2008). Hormonal responses and endurance adaptations. *European Journal of Applied Physiology, 103*(5), 573–581.
23. Grandy, S. A., & Majerczak, J. (2008). Hormonal responses to training. *Journal of Applied Physiology*.
24. Hicks, A. L., Kent-Braun, J., & Ditor, D. S. (2001). Sex differences in human skeletal muscle fatigue. *Exercise and Sport Sciences Reviews, 29*(3), 109–112.
25. Howley, E. T., Bassett, D. R., & Welch, H. G. (1995). Criteria for maximal oxygen uptake. *Medicine & Science in Sports & Exercise, 27*(9), 1292–1301.
26. Ignacio, R., et al. (2007). Fitness and adiposity in children. *Pediatric Exercise Science*.
27. Jackson, A. S., & Hopkinson, N. S. (2009). Skeletal muscle dysfunction in COPD. *Thorax*.
28. Kline, G. M., Porcari, J. P., Hintermeister, R., et al. (1987). Estimation of VO_2max from a one-mile walk test. *Research Quarterly for Exercise and Sport, 58*(1), 7–11.
29. Kraemer, W. J., & Ratamess, N. A. (2005). Hormonal responses and adaptations to resistance exercise. *Sports Medicine, 35*(4), 339–361.
30. Kraemer, W. J., & Ratamess, N. A. (2005). Hormonal responses to resistance exercise. *Sports Medicine, 35*(4), 339–361.
31. Maltais, F., et al. (2014). Skeletal muscle dysfunction in COPD. *American Journal of Respiratory and Critical Care Medicine, 189*(1), 9–21.
32. Marie, S. K. N., et al. (2008). Aerobic training in muscular dystrophy. *Neuromuscular Disorders*.
33. McArdle, W. D., Katch, F. I., & Katch, V. L. (1996). *Exercise physiology: Energy, nutrition, and human performance* (4th ed.). Williams & Wilkins.
34. McArdle, W. D., Katch, F. I., & Katch, V. L. (2015). *Exercise physiology: Nutrition, energy, and human performance*. Lippincott Williams & Wilkins.
35. Mika, A., et al. (2008). Cross-education effects. *Journal of Physiology*.
36. Mujika, I., & Padilla, S. (2000). Detraining effects. *Sports Medicine, 30*(2), 79–87.
37. Munn, J., et al. (2004). Cross-education meta-analysis. *Journal of Applied Physiology*.

38. Munn, J., Herbert, R. D., & Gandevia, S. C. (2004). Contralateral strength training effects. *Journal of Applied Physiology, 96*(5), 1861–1866.
39. Munn, J., Herbert, R. D., & Gandevia, S. C. (2004). Contralateral strength training effects. *Journal of Applied Physiology, 96*(5), 1861–1866.
40. Nygaard, E. (1977). Skeletal muscle fibre characteristics in women. *Acta Physiologica Scandinavica, 100*(3), 1–32.
41. References
42. Reilly, T., & Ekblom, B. (2005). The use of recovery methods post-exercise. *Journal of Sports Sciences, 23*(6), 619–627.
43. Røsler, K. M., & Hoppeler, H. (1985). Muscle adaptations to endurance training. *European Journal of Applied Physiology*.
44. Schulz, K. F., Altman, D. G., & Moher, D. (2010). CONSORT guidelines. *BMJ, 340*, c332.
45. Soyupek, F., et al. (2006). Exercise effects on hand function. *Clinical Rehabilitation*.
46. Tanaka, H., Monahan, K. D., & Seals, D. R. (2001). Age-predicted HRmax. *Journal of the American College of Cardiology, 37*(1), 153–156.
47. Thomas, S., Reading, J., & Shephard, R. J. (1992). PAR-Q validation. *Canadian Journal of Sport Sciences*.
48. Triscott, S., et al. (2008). Neural fatigue adaptations. *Neuroscience Letters*.
49. Vilaró, J., et al. (2009). Muscle dysfunction in COPD. *European Respiratory Journal*.
50. Vilaró, J., Ramírez-Sarmiento, A., Martínez-Llorens, J., et al. (2009). Muscle dysfunction and exercise limitation in COPD. *European Respiratory Journal, 33*(5), 1030–1038.
51. Vincent, K. R., et al. (2002). Resistance training effects in elderly. *Journal of Gerontology*.
52. Warburton, D. E., Nicol, C. W., & Bredin, S. S. (2006). Health benefits of physical activity. *CMAJ, 174*(6), 801–809.
53. Wilmore, J. H., & Costill, D. L. (2004). *Physiology of sport and exercise* (3rd ed.). Human Kinetics.
54. World Health Organization. (2000). *Obesity: Preventing and managing the global epidemic*.
55. World Medical Association. (2013). Declaration of Helsinki.
56. Yates, J. W. (1983). Cross-limb fatigue effects. *Journal of Applied Physiology*.