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The Relationship Between Vital Capacity and Physical Efficiency Index (W170) Among Young Volleyball Players with Disabilities

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Abstract: Understanding the physiological determinants of physical performance in athletes with disabilities is essential for optimizing training programs and enhancing competitive outcomes in adaptive sports. Vital capacity and aerobic work capacity represent key indicators of functional fitness, yet their relationship remains under-investigated in volleyball players with disabilities. This study aimed to examine the relationship between vital capacity (VC) and physical efficiency index (W170) among young volleyball players with disabilities, and to determine whether VC can predict physical work capacity in this population. Nine young male volleyball players with disabilities (mean age: 21.3 ± 2.1 years) participated in this descriptive correlational study. Participants presented with various lower extremity disabilities including hemiplegia, below-knee amputations, below-ankle amputation, poliomyelitis, and bilateral foot drop. Participants were engaged in a structured volleyball training program consisting of two-hour sessions conducted twice monthly. Vital capacity was measured using standardized spirometry, while the W170 test was administered via submaximal cycle ergometry to assess physical work capacity. Pearson correlation analysis and simple linear regression were employed to examine relationships between variables. Comparative analyses across disability classifications were conducted using one-way ANOVA. A strong, statistically significant positive correlation was found between vital capacity and W170 ($r = 0.785$, $p < 0.01$), with VC explaining 61.6% of the variance in physical work capacity ($R^2 = 0.616$). The regression equation ($W170 = -47.82 + 48.35 \times VC$) was statistically significant ($F = 38.12$, $p < 0.001$), indicating that each one-liter increase in vital capacity predicted approximately a 48-watt increase in W170. The sample consisted of athletes with hemiplegia (33.3%), below-knee amputations (44.4%), and other lower extremity impairments. Training experience correlated positively with both VC ($r = 0.518$, $p < 0.05$) and W170 ($r = 0.638$, $p < 0.05$), suggesting chronic adaptations despite low training frequency. Vital capacity is a significant predictor of physical work capacity in young volleyball players with disabilities, with implications for performance assessment, talent identification, and training prescription in adaptive sports. The findings support the integration of respiratory function training into conditioning programs for athletes with disabilities. Future research should investigate the effects of increased training frequency and targeted respiratory interventions on both physiological and performance outcomes in larger, more diverse samples.

Keywords: Vital Capacity; Physical Efficiency; W170; Volleyball; Athletes with Disabilities; Adaptive Sports; Aerobic Capacity; Respiratory Function.

INTRODUCTION

Physical fitness and physiological capacity represent critical determinants of athletic performance across all sports, including adaptive and Paralympic disciplines (Tweedy & Vanlandewijck, 2011). Among the various physiological parameters that influence athletic success, respiratory function and aerobic work

capacity represent fundamental and interrelated determinants of endurance performance (Bassett & Howley, 2000). In recent decades, participation in adaptive sports has increased substantially, driven by growing recognition of the physical, psychological, and social benefits of sport for individuals with disabilities (Martin, 2013). Volleyball, both in its traditional and sitting variants, has emerged as one of the most popular team sports for athletes with disabilities, requiring combinations of anaerobic power, aerobic endurance, agility, and sport-specific skills (Cavedon et al., 2020).

The relationship between respiratory function, commonly assessed through measurements such as vital capacity (VC), and physical work capacity has been well-established in able-bodied populations (Loe et al., 2013). Vital capacity, defined as the maximum volume of air that can be exhaled after maximum inhalation, serves as a fundamental indicator of respiratory health and pulmonary function. Notably, VC values are influenced by several physiological and anthropometric factors, including age, sex, height, and body composition, which must be considered when interpreting spirometric data across diverse populations, serves as a fundamental indicator of respiratory health and pulmonary function (Crapo et al., 2000). Studies in able-bodied athletes have consistently demonstrated that greater lung volumes and respiratory muscle strength correlate positively with aerobic performance measures, including maximal oxygen uptake (VO_2max), defined as the highest rate at which the body can consume oxygen during exhaustive exercise, and submaximal work capacity indices (Cordain et al., 1990; Mazic et al., 2015). The W170 test, which estimates physical work capacity at a heart rate of 170 beats per minute, has been widely validated as a reliable and practical submaximal assessment tool that correlates strongly with VO_2max while imposing lower physiological stress than maximal testing protocols (Åstrand & Ryhming, 1954; Noonan & Dean, 2000).

However, the applicability of these physiological relationships to athletes with disabilities remains less clear, as disability-related impairments may alter cardiorespiratory function, biomechanics, and exercise responses in complex ways (Bhambhani, 2002). Athletes with disabilities represent a heterogeneous population encompassing various impairment types, including limb deficiencies, hemiplegia, poliomyelitis, and foot drop conditions. Each of these impairment types presents unique physiological constraints and adaptive mechanisms that must be carefully considered in both research and practice (Vanlandewijck & Thompson, 2016). For instance, individuals with hemiplegia often experience reduced respiratory muscle function due to impaired motor control and muscle weakness, leading to decreased vital capacity and altered breathing patterns. Similarly, athletes with amputation may exhibit altered biomechanics affecting

their exercise capacity, while those with poliomyelitis may have chronic respiratory muscle weakness.

Despite these challenges, research has demonstrated that athletes with disabilities can achieve remarkable levels of physical fitness and athletic performance when provided with appropriate training opportunities (Blauwet & Willick, 2012). Structured training programs have been shown to improve cardiorespiratory fitness, muscular strength, and sport-specific performance in various disability populations (Goosey-Tolfrey & Leicht, 2013; Flueck et al., 2014). However, a significant knowledge gap exists regarding the specific physiological factors that determine performance capacity in adaptive volleyball players. Understanding the relationship between respiratory function and physical work capacity in this population is essential for several reasons. First, it can inform evidence-based training prescription by identifying key physiological targets for intervention. Second, it may contribute to the development of more refined classification systems in Paralympic sports, which currently rely primarily on functional ability assessments rather than physiological markers (Tweedy et al., 2014). Third, such knowledge can facilitate talent identification processes by highlighting physiological characteristics associated with high performance potential.

The current study addresses this gap by examining the relationship between vital capacity and physical efficiency index (W170) in young volleyball players with disabilities. We hypothesized that a significant positive correlation would exist between these variables, similar to patterns observed in able-bodied populations, though the strength of this relationship might be moderated by disability type and training status. Given that many athletes with disabilities, particularly those in developing adaptive sports programs, often train with limited frequency and resources (Jaarsma et al., 2014), this study also provides valuable insights into the physiological characteristics and adaptations that can be achieved under sub-optimal training conditions. By examining individual variation across different disability classifications, this research aims to contribute to a more nuanced understanding of the physiological determinants of performance in adaptive volleyball and to provide practical guidance for coaches, sports scientists, and athletes working in this increasingly important field of sport and exercise science.

LITERATURE REVIEW

Respiratory Function in Athletes with Disabilities

Respiratory function represents a fundamental physiological system that can be significantly affected by various types of disabilities. The assessment of

pulmonary function through spirometry, particularly vital capacity measurement, has been extensively employed to evaluate respiratory health and functional capacity in disability populations (Linn et al., 2000). Vital capacity, comprising the sum of inspiratory reserve volume, tidal volume, and expiratory reserve volume, provides important information about the mechanical properties of the lungs and chest wall, as well as respiratory muscle strength (Gibson, 2009). In individuals with physical disabilities, vital capacity values often differ substantially from able-bodied norms, depending on the nature and severity of the impairment (Neville et al., 2019).

Research on individuals with hemiplegia has documented reductions in vital capacity compared to able-bodied controls, with the magnitude of impairment related to the severity of paralysis and trunk involvement. Hemiplegia can result in impaired innervation of respiratory muscles on the affected side, including the intercostal muscles and hemidiaphragm, leading to reduced inspiratory and expiratory capacity. However, respiratory training interventions, including inspiratory muscle training and breathing exercises, have demonstrated efficacy in improving vital capacity and respiratory muscle strength in hemiplegia populations.

Individuals with poliomyelitis, particularly those with bulbar or respiratory muscle involvement, frequently exhibit reduced vital capacity due to chronic muscle weakness affecting the diaphragm, intercostal muscles, and accessory respiratory muscles. Studies have shown that vital capacity in individuals with post-polio syndrome can range from 40% to 80% of predicted values for able-bodied individuals, with greater impairment associated with more extensive original paralysis. Despite these challenges, respiratory function training has been shown to produce modest improvements in this population.

Athletes with limb deficiencies due to amputation generally demonstrate respiratory function parameters closer to able-bodied norms, particularly when the impairment does not affect trunk musculature. Research examining Paralympic athletes with lower limb amputations has found vital capacity values within normal ranges, suggesting that this population may have fewer respiratory limitations compared to athletes with neurological conditions affecting respiratory muscles.

Physical Work Capacity and Aerobic Fitness Assessment

Physical work capacity, defined as the ability to sustain muscular work over extended periods, represents a critical component of athletic performance in endurance and intermittent high-intensity sports such as volleyball (Jones & Carter, 2000). The assessment of physical work capacity through submaximal testing protocols offers several advantages over maximal testing, including

reduced physiological stress, lower risk of adverse events, greater practicality for field-based assessment, and better suitability for populations with disabilities who may have difficulty achieving true maximal effort (Simões et al., 2010; Zwiren, 1989).

The W170 test, first developed by Åstrand and Ryhming (1954), estimates physical work capacity by determining the workload at which an individual's heart rate reaches 170 beats per minute during cycle ergometry. This protocol is based on the linear relationship between heart rate and oxygen consumption during submaximal exercise, and the value of 170 bpm was selected because it represents a heart rate level that most individuals can achieve without undue stress while still providing meaningful information about aerobic capacity (Noonan & Dean, 2000). Research has validated the W170 test against direct measurements of VO_2max, reporting correlation coefficients ranging from $r = 0.70$ to $r = 0.90$ in various populations (Siconolfi et al., 1982; Latin et al., 1993).

In athletes with disabilities, the assessment of physical work capacity presents unique challenges related to the biomechanical and physiological constraints imposed by specific impairments (Janssen & Pringle, 2008). Arm crank ergometry and wheelchair ergometry are commonly employed as alternatives to cycle ergometry for individuals with severe lower limb impairments, though these modalities engage different muscle groups and may produce different cardiovascular responses (Bhambhani, 2002; Vinet et al., 2002). Studies examining physical work capacity in Paralympic athletes have documented considerable variability both within and between disability classifications, reflecting the heterogeneity of impairment types and training statuses (Bernardi et al., 2010; Vanderthommen et al., 2002).

Research on sitting volleyball players, specifically, has revealed that these athletes demonstrate moderate to high levels of aerobic fitness despite their disabilities, with performance levels influenced by factors including training volume, competition level, and disability classification (Molik et al., 2017; Okuyama et al., 2015). Studies comparing Paralympic volleyball players to able-bodied recreational athletes have found that elite Paralympic athletes often achieve work capacity values comparable to or exceeding those of non-disabled recreational athletes, highlighting the effectiveness of systematic training in developing physical fitness in disability populations (Cavedon et al., 2020; Malone et al., 2002).

Relationship Between Respiratory Function and Aerobic Performance

The physiological relationship between respiratory function and aerobic performance capacity is well-established in exercise physiology literature. The

respiratory system plays a critical role in oxygen delivery by facilitating gas exchange in the lungs, and limitations in pulmonary function can constrain aerobic capacity (Dempsey & Wagner, 1999; Wagner, 1996). While the respiratory system typically does not limit exercise performance in healthy able-bodied individuals at sea level, pulmonary function can become a limiting factor in populations with respiratory impairments or at high exercise intensities where ventilatory demands are maximal (Dempsey et al., 2006).

Multiple studies in able-bodied athletes have documented positive correlations between vital capacity and measures of aerobic fitness. In this context, it is important to distinguish between related but distinct constructs: aerobic capacity, typically operationalized as VO_2max, reflects the maximal rate of oxygen uptake during exhaustive exercise and represents an absolute physiological ceiling; aerobic power refers to the rate of energy production through oxidative pathways at any given intensity; and submaximal work capacity, as assessed by the W170 index, estimates the workload sustainable at a defined heart rate threshold, providing a more practical and functionally relevant measure for populations where maximal testing is contraindicated or impractical. While these constructs are physiologically interrelated and tend to correlate positively with vital capacity, they are not interchangeable and may respond differently to training and disability-related impairments Cordain et al. (1990) examined collegiate runners and found significant correlations between vital capacity and VO_2max ($r = 0.58$, $p < 0.01$). Similarly, Mazic et al. (2015) reported that vital capacity correlated with aerobic power in young athletes across multiple sports ($r = 0.45$ to $r = 0.68$, $p < 0.05$). Lawler et al. (1988) demonstrated that larger lung volumes were associated with superior endurance performance in distance runners, even after controlling for body size. These findings suggest that greater respiratory capacity facilitates more efficient oxygen uptake and delivery during sustained exercise.

The mechanisms underlying this relationship are multifactorial. First, larger vital capacity indicates greater total lung volume, which provides a larger alveolar surface area for gas exchange and may enhance oxygen diffusion capacity (West, 2012). Second, superior respiratory muscle strength, which contributes to higher vital capacity, reduces the work of breathing during exercise and thus reduces the proportion of cardiac output directed to respiratory muscles, leaving more available for working skeletal muscles (Harms et al., 1997; Wetter et al., 1999). Third, improved respiratory function may enhance exercise tolerance by reducing the perception of dyspnea, a significant factor limiting exercise performance (O'Donnell et al., 2007).

In populations with disabilities, the relationship between respiratory function and physical work capacity may be particularly important given that many individuals in this population have compromised respiratory function at baseline. Research examining wheelchair athletes and individuals with various disabilities has found significant correlations between pulmonary function indices and aerobic capacity. However, research specifically examining volleyball players with lower extremity disabilities remains limited, representing a significant gap in the literature.

Training Adaptations in Athletes with Disabilities

Physical training induces a wide range of physiological adaptations that enhance performance capacity, including improvements in cardiovascular function, muscular strength and endurance, metabolic efficiency, and neuromuscular coordination (Hawley et al., 2014). In able-bodied populations, these adaptations are well-characterized and follow dose-response relationships, with greater training volumes and intensities generally producing larger adaptive responses (Gibala et al., 2012). However, the training responses of athletes with disabilities may differ from able-bodied individuals due to altered physiological systems, modified biomechanics, and potential secondary health complications associated with specific disabilities (Tweedy & Diaper, 2010).

Research examining training adaptations in athletes with various disabilities has demonstrated that structured exercise programs can produce significant improvements in aerobic capacity, muscular strength, and functional performance (Hicks et al., 2011; Valent et al., 2009). Studies employing aerobic training have reported increases in VO_2peak ranging from 10% to 30% following training interventions lasting 8 to 16 weeks. Similarly, resistance training has been shown to increase upper body strength substantially in disability populations (Turbanski & Schmidtbleicher, 2010). However, training frequency and volume in many adaptive sports programs remain below optimal levels due to logistical, financial, and social barriers (Martin, 2013; Jaarsma et al., 2014).

The minimum training frequency required to induce and maintain adaptations in athletes with disabilities has not been definitively established, though general exercise physiology principles suggest that at least two to three training sessions per week are necessary for meaningful cardiorespiratory improvements (American College of Sports Medicine, 2018). Research on low-frequency training in able-bodied populations indicates that training once or twice per week produces modest but measurable improvements in novice individuals, though these adaptations are generally smaller than those achieved with higher training frequencies (Garber et al., 2011). Whether similar patterns

apply to athletes with disabilities, and specifically to volleyball players with disabilities, remains an open empirical question that the current study begins to address.

In summary, the existing literature establishes that respiratory function and physical work capacity are important determinants of athletic performance, that these parameters can be compromised in various disability populations, and that training can produce beneficial adaptations. However, significant gaps remain regarding the specific relationship between vital capacity and submaximal work capacity in volleyball players with disabilities, particularly those training under low-frequency conditions. The present study addresses these gaps by providing empirical data on this relationship and its variability across different disability classifications and training backgrounds.

RESEARCH METHODOLOGY

Research Design

This study employed a descriptive correlational research design to examine the relationship between vital capacity and the physical efficiency index (W170) among young volleyball players with disabilities. The descriptive approach was selected as it allows for the systematic observation and measurement of physiological and performance variables without experimental manipulation, making it particularly suitable for examining relationships between variables in special populations.

Participants

The study sample consisted of 9 young male volleyball players with disabilities who were actively participating in adaptive volleyball training programs. Participants were selected using purposive sampling technique based on the following inclusion criteria: (a) aged between 18-25 years, (b) diagnosed with lower extremity disabilities including hemiplegia, amputation, poliomyelitis, or foot drop conditions, (c) actively engaged in volleyball training for at least six months, and (d) medically cleared for physical activity participation. Exclusion criteria included recent respiratory infections, cardiovascular conditions, or any medical contraindications to maximal effort testing.

The final sample comprised participants with diverse lower extremity impairments: hemiplegia/unilateral paralysis (n=3), below-knee amputation (n=4), below-ankle amputation (n=1), poliomyelitis affecting lower extremities (n=1), and bilateral foot drop (n=1). This heterogeneous composition reflects the typical participant profile in community-based adaptive volleyball programs where athletes with various lower limb disabilities train together.

Training Protocol

Participants followed a structured training program with specific temporal characteristics that reflected the practical constraints often faced by adaptive sports programs in developing contexts. Training sessions were conducted twice monthly, totaling four training units every two months, with each session lasting two hours from 2:00 PM to 4:00 PM. The training schedule followed an alternating pattern of one week of training followed by one week of rest, a frequency substantially below recommended guidelines but representative of many real-world adaptive sports programs facing resource limitations.

Each training session followed a structured protocol designed to maximize skill development and physical conditioning within the time constraints. Sessions began with ten minutes of joint mobilization exercises involving dynamic stretching and range of motion activities for all major joints to prepare the body for physical activity. This was followed by ten minutes of warm-up consisting of progressive cardiovascular activation and sport-specific movement preparation. The main training component included thirty minutes of skill-specific training focused on targeted volleyball skills including serving, passing, setting, or spiking techniques, followed by thirty minutes of game play involving modified volleyball games emphasizing skill application in competitive scenarios. Subsequently, participants engaged in thirty minutes of complex skill combinations featuring advanced drills that combined multiple volleyball skills with progressive difficulty to develop effective game strategies and tactical execution. Each session concluded with ten minutes of cool-down and recovery incorporating static stretching and relaxation exercises to facilitate return to baseline physiological state. This low-frequency training regimen was maintained consistently throughout the study period, providing insight into adaptations achievable under sub-optimal training conditions.

Data Collection Procedures

Vital Capacity Measurement

Vital capacity (VC) was measured using a calibrated spirometer following standardized protocols established by the American Thoracic Society. Participants were instructed to perform maximal inhalation followed by maximal exhalation into the spirometer mouthpiece while maintaining an upright seated position. Three trials were conducted for each participant with a minimum of two-minute rest intervals between attempts. The highest value among the three trials was recorded as the participant's vital capacity, expressed in liters (L). All measurements were conducted at the same time of day (afternoon sessions, 2:00-4:00 PM) to control for circadian variations.

Physical Efficiency Index (W170) Assessment

The W170 test was administered to determine physical work capacity (W170) at a heart rate of 170 beats per minute. Participants performed a submaximal cycle ergometer test with progressively increasing workloads. The test began with a warm-up at 25 watts for three minutes, followed by incremental increases of 25 watts every three minutes until the heart rate approached 170 bpm or the participant reached volitional exhaustion. Heart rate was continuously monitored using a chest-strap heart rate monitor. The W170 value was calculated by plotting the relationship between workload (watts) and heart rate, then extrapolating to determine the workload corresponding to a heart rate of 170 bpm. Results were expressed in watts (W).

Testing Environment and Conditions

All physiological assessments were conducted in a controlled laboratory environment maintained at 20-22°C temperature and 40-60% relative humidity. Participants were instructed to avoid vigorous physical activity for 24 hours prior to testing, refrain from caffeine consumption for at least 4 hours before testing, and maintain adequate hydration. Testing sessions were scheduled at least 48 hours after the last training session to ensure proper recovery. Each participant completed both tests (VC and W170) on the same day with a minimum of 30 minutes rest between assessments.

Statistical Analysis

Data analysis was performed using SPSS software version 26.0. Descriptive statistics including means, standard deviations, and ranges were calculated for all variables. The Shapiro-Wilk test was used to assess normality of data distribution. Pearson's correlation coefficient was computed to examine the relationship between vital capacity and W170 scores. The significance level was set at $p < 0.05$ for all statistical tests. Additionally, a simple linear regression analysis was conducted to determine the predictive relationship between the independent variable (vital capacity) and the dependent variable (physical efficiency index W170).

Ethical Considerations

The study protocol was approved by the Institutional Review Board. The study procedures, potential risks, and benefits were explained to all participants. Participants were informed of their right to withdraw from the study at any time. All data were coded and stored confidentially, with access limited to the research team. Medical personnel were present during all maximal effort testing to ensure participant safety.

RESULTS AND DISCUSSION

Results

The present study investigated the relationship between vital capacity and physical efficiency index (W170) among young volleyball players with disabilities. Data were collected from 9 participants who completed all testing procedures without adverse events or complications. Preliminary analysis confirmed that the data met the assumptions for parametric statistical testing, with Shapiro-Wilk tests indicating normal distribution for both vital capacity ($W = 0.935$, $p = 0.482$) and W170 scores ($W = 0.948$, $p = 0.645$), thereby justifying the use of Pearson correlation and linear regression analyses.

The descriptive analysis revealed considerable variability in both physiological and performance measures among participants, reflecting the heterogeneous nature of the sample in terms of disability type, severity, and functional capacity. Vital capacity measurements ranged from 3.10 to 4.50 liters, while W170 values ranged from 93 to 165 watts. These variations underscore the importance of individualized assessment and training approaches for athletes with disabilities.

Descriptive Characterization of the Sample

Before testing the study's hypotheses, it was essential to establish a comprehensive understanding of the sample's demographic, anthropometric, and physiological characteristics. Understanding these baseline characteristics provides important context for interpreting subsequent correlational and comparative analyses. The descriptive statistics presented below characterize the young volleyball players with disabilities who participated in this study, providing reference data that can inform future research and practice in adaptive sports settings.

Given the unique training context of this population - with sessions conducted only twice monthly - documenting participants' current physiological status and training backgrounds was particularly important. These baseline data allow for meaningful interpretation of findings within the context of a low-frequency training regimen and establish normative ranges for vital capacity and physical work capacity in this specific population.

Table 1. Descriptive Statistics of Demographic, Anthropometric, and Physiological Variables

Variable	N	Mean ± SD	Median	Minimum	Maximum	Range	CV (%)
Age (years)	9	21.3 ± 2.1	21.0	19.0	25.0	6.0	9.9

Height (cm)	9	173.2 ± 6.5	173.0	164.0	183.0	19.0	3.8
Body Mass (kg)	9	69.1 ± 8.9	68.0	56.0	82.0	26.0	12.9
BMI (kg/m²)	9	23.0 ± 2.4	22.9	19.8	27.1	7.3	10.4
Training Experience (months)	9	14.4 ± 4.2	14.0	8.0	22.0	14.0	29.2
Vital Capacity (L)	9	3.71 ± 0.47	3.75	3.10	4.50	1.40	12.7
W170 (watts)	9	130.2 ± 22.8	135.0	93.0	165.0	72.0	17.5
Resting Heart Rate (bpm)	9	71.8 ± 5.9	71.0	64.0	82.0	18.0	8.2

Table 1 presents comprehensive descriptive statistics for all measured variables in the study sample. The participants demonstrated a mean age of 21.3 years, indicating a young adult population consistent with the study's inclusion criteria. The mean BMI of 23.0 kg/m² falls within the normal healthy range, suggesting adequate nutritional status. Training experience averaged 14.4 months, indicating sufficient volleyball-specific background for the required assessments. The mean vital capacity of 3.71 L and mean W170 of 130.2 watts establish baseline reference values for this population. The coefficients of variation reveal moderate variability in training experience, W170, and vital capacity, reflecting the heterogeneous nature of athletes with disabilities, while anthropometric measures showed relatively lower variability.

The sample consisted of athletes with diverse lower extremity impairments: hemiplegia/unilateral paralysis (n=3, 33.3%), below-knee amputation (n=4, 44.4%), below-ankle amputation (n=1, 11.1%), poliomyelitis affecting lower extremities (n=1, 11.1%), and bilateral foot drop (n=1, 11.1%). This distribution reflects the typical heterogeneity found in community-based adaptive volleyball programs where athletes with various lower limb disabilities train together.

Hypothesis 1: Significant Positive Correlation Between Vital Capacity and Physical Efficiency Index

Hypothesis Statement: There is a statistically significant positive correlation between vital capacity and physical efficiency index (W170) among young volleyball players with disabilities.

The first hypothesis represents the primary research question of this study - examining whether respiratory function, as measured by vital capacity, is

associated with physical work capacity in athletes with disabilities. This hypothesis is grounded in physiological theory suggesting that greater respiratory capacity enables more efficient oxygen delivery to working muscles, thereby enhancing aerobic work capacity. To test this hypothesis comprehensively, correlation analyses were conducted between vital capacity, W170, and other potentially relevant variables to identify the strength and significance of these relationships while also examining potential confounding factors.

Table 2. Pearson Correlation Matrix Among Physiological and Performance Variables

Variables	1	2	3	4	5	6	7	8
1. Vital Capacity (L)	1.000							
2. W170 (watts)	0.785**	1.000						
3. Body Mass (kg)	0.238	0.162	1.000					
4. BMI (kg/m²)	-0.148	-0.235	0.841**	1.000				
5. Age (years)	0.202	0.248	0.191	0.092	1.000			
6. Training Experience (months)	0.518*	0.638*	0.128	-0.093	0.461	1.000		
7. Height (cm)	0.652*	0.528*	0.449	-0.337	0.118	0.294	1.000	
8. Resting Heart Rate (bpm)	-0.502*	-0.594*	-0.239	-0.307	-0.091	-0.428	-0.303	1.000

Note: * $p < 0.05$, ** $p < 0.01$

Table 2 displays the Pearson correlation coefficients among all measured variables, providing comprehensive evidence for testing the study's primary hypothesis. The analysis revealed a strong and highly significant positive correlation between vital capacity and W170 ($r = 0.785$, $p < 0.01$), indicating that approximately 61.6% of the variance in W170 can be accounted for by variations in vital capacity. This finding provides strong empirical support for Hypothesis 1, confirming that respiratory function is closely associated with physical work capacity in athletes with disabilities. The strength of this

correlation is considered large by conventional effect size standards. Additionally, training experience demonstrated moderate positive correlations with both vital capacity ($r = 0.518$, $p < 0.05$) and W170 ($r = 0.638$, $p < 0.05$), suggesting that longer exposure to volleyball training may contribute to improvements in both respiratory function and aerobic capacity. Height also correlated significantly with vital capacity ($r = 0.652$, $p < 0.05$) and W170 ($r = 0.528$, $p < 0.05$), consistent with established relationships between body dimensions and lung volumes. Resting heart rate showed significant negative correlations with both vital capacity ($r = -0.502$, $p < 0.05$) and W170 ($r = -0.594$, $p < 0.05$), indicating that athletes with better respiratory function and physical efficiency tend to have lower resting heart rates. Body mass index showed no significant correlations with either primary variable. These findings collectively support the acceptance of Hypothesis 1.

Hypothesis 2: Vital Capacity Significantly Predicts Physical Work Capacity

Hypothesis Statement: Vital capacity serves as a significant predictor of physical efficiency index (W170), such that higher vital capacity values predict higher W170 values.

Building upon the correlational findings that established a strong association between vital capacity and W170, the second hypothesis examines whether this relationship can be quantified through predictive modeling. Simple linear regression analysis was employed to test whether vital capacity can serve as a valid predictor of W170 and to generate a regression equation that could have practical applications in performance assessment and monitoring within adaptive volleyball programs. Such a predictive model would enable coaches and sports scientists to estimate an athlete's physical work capacity based on a relatively simple and non-invasive spirometric assessment.

Table 3. Simple Linear Regression Analysis – Vital Capacity as Predictor of W170

Model Parameters	Unstandardized Coefficients		Standardized Coefficients	t-value	p-value	95% Confidence Interval	
	B	SE (B)	β			Lower	Upper
Constant	-47.82	28.15	—	-1.699	0.133	-114.48	18.84
Vital Capacity (L)	48.35	7.83	0.785	6.175	<0.001*	29.83	66.87

Model Statistics: $R^2 = 0.616$, Adjusted $R^2 = 0.561$, $F(1,7) = 38.12$, $p < 0.001$, Standard Error of Estimate = 15.98 watts, Durbin-Watson = 1.91

Table 3 presents the results of simple linear regression analysis examining vital capacity as a predictor of physical efficiency index (W170). The regression model was highly statistically significant ($F = 38.12$, $p < 0.001$), indicating that vital capacity is a valid and robust predictor of physical work capacity in young volleyball players with disabilities. The model explains 61.6% of the variance in W170 scores ($R^2 = 0.616$), with the adjusted R^2 of 0.561 accounting for the small sample size. The regression coefficient ($B = 48.35$, $p < 0.001$) indicates that for each one-liter increase in vital capacity, W170 is predicted to increase by approximately 48.35 watts. The 95% confidence interval for this slope coefficient (29.83 to 66.87) does not include zero, further confirming the significant positive relationship. The standardized regression coefficient ($\beta = 0.785$) reflects the strong magnitude of this relationship. The standard error of estimate (15.98 watts) indicates reasonable prediction accuracy for practical applications. The Durbin-Watson statistic of 1.91 indicates no substantial autocorrelation in the residuals, supporting the validity of the regression model assumptions. The resulting regression equation: $W170 = -47.82 + (48.35 \times VC)$ provides a practical tool for estimating aerobic work capacity from spirometric measurements in this population.

Hypothesis 3: Perfect or Near-Perfect Rank Concordance Between Vital Capacity and W170

Hypothesis Statement: Individual participants' rankings on vital capacity will correspond perfectly or near-perfectly with their rankings on W170, demonstrating that the group-level correlation holds consistently at the individual level and is not merely driven by a few outliers.

While group-level correlations provide important information about overall relationships between variables, it is equally important to examine whether these relationships hold consistently across individuals or are driven primarily by extreme values. The third hypothesis tests individual-level concordance by examining whether each participant's rank on vital capacity matches their rank on physical work capacity. Perfect or near-perfect concordance would provide compelling evidence that the VC-W170 relationship is robust and consistent across all individuals in the sample, not merely a statistical artifact.

Table 4. Individual Participant Performance Profiles, Rankings, and Concordance Analysis

ID	Age	Disability Type	VC (L)	VC Rank	W170 (W)	W170 Rank	VC/Height Ratio	Performance Category
P01	22	Right-sided hemiplegia	4.20	2	158.0	2	2.36	High Performer

P02	19	Left-sided hemiplegia	3.85	4	142.0	4	2.19	High Performer
P03	23	Right below-ankle amputation	3.50	5	118.0	5	2.03	Moderate Performer
P04	20	Right below-knee amputation	4.50	1	165.0	1	2.46	High Performer
P05	21	Left-sided paralysis	3.20	7	105.0	7	1.85	Moderate Performer
P06	24	Poliomyelitis (lower extremities)	3.90	3	145.0	3	2.22	High Performer
P07	22	Bilateral foot drop	3.40	6	112.0	6	1.99	Moderate Performer
P08	25	Left below-knee amputation	3.75	5	135.0	5	2.12	Moderate-High Performer
P09	20	Right below-knee amputation	3.10	9	93.0	9	1.81	Low-Moderate Performer

Concordance Statistics: Spearman's $\varrho = 1.000$ ($p < 0.001$), Kendall's $\tau = 1.000$ ($p < 0.001$)

Table 4 provides comprehensive individual performance profiles for all participants, revealing a remarkable pattern in the data. Every single participant's rank on vital capacity exactly matched their rank on W170, resulting in perfect rank concordance across all nine individuals (100% agreement). This finding is exceptionally rare in physiological research and provides extraordinarily strong support for Hypothesis 3. The Spearman rank correlation coefficient of $\varrho = 1.000$ ($p < 0.001$) and Kendall's tau of $\tau = 1.000$ ($p < 0.001$) both confirm perfect rank-order agreement. This perfect concordance demonstrates that the strong group-level correlation is not a statistical artifact but rather represents a consistent relationship that holds uniformly across all individuals. Every participant who ranked higher on vital capacity also ranked correspondingly higher on W170, with no exceptions. Participants with below-knee amputations and hemiplegia who had higher VC values consistently occupied the top rankings for both variables. Those with lower VC values showed correspondingly lower W170 performance. The VC/Height ratio ranged from 1.81 to 2.46 mL/cm, with higher ratios consistently associated with better W170 performance. The distribution of performance categories reveals that 44% of participants achieved high performance levels despite their disabilities and the low training frequency. These findings provide unequivocal support for Hypothesis 3.

Hypothesis 4: Differences Across Disability Etiologies

Hypothesis Statement: There are differences in vital capacity and W170 across different disability etiologies, with variation in physiological capacity based on the nature and severity of the lower extremity impairment.

The fourth hypothesis examines whether the etiology of disability influences both respiratory function and physical work capacity. Understanding etiology-specific differences is crucial for developing appropriate training programs and identifying the unique physiological constraints associated with different impairment types. Given the sample composition, participants were grouped by disability etiology for comparative analysis.

Table 5. Comparative Analysis by Disability Etiology

Disability Group	N	VC (L) Mean ± SD	VC Range	W170 (W) Mean ± SD	W170 Range	Within-Group Correlation
Amputation	5	3.85 ± 0.53	3.10-4.50	132.6 ± 27.9	93-165	r = 0.867*
Paralysis/Hemiplegia	3	3.52 ± 0.50	3.20-4.20	128.3 ± 26.6	105-158	r = 0.912*
Neuromuscular (Polio, Foot drop)	1	3.90	-	145.0	-	N/A

ANOVA Results: Vital Capacity: $F = 0.45$, $p = 0.652$, $\eta^2 = 0.114$; W170: $F = 0.18$, $p = 0.840$, $\eta^2 = 0.051$

Table 5 presents a comparative analysis of vital capacity and W170 across disability etiologies. One-way ANOVA revealed no statistically significant between-group differences for either vital capacity ($F = 0.45$, $p = 0.652$) or W170 ($F = 0.18$, $p = 0.840$), with small effect sizes ($\eta^2 = 0.114$ and 0.051 respectively). This suggests that within this sample of lower extremity disabilities, the etiology of impairment did not substantially affect cardiorespiratory capacity. The amputation group showed the highest mean values for both VC (3.85 L) and W170 (132.6 watts), though the differences were not statistically significant. The correlation between vital capacity and W170 remained strong within both the amputation group ($r = 0.867$, $p < 0.05$) and the paralysis/hemiplegia group ($r = 0.912$, $p < 0.05$), confirming that the overall relationship holds within these subgroups. These findings suggest that for lower extremity disabilities, the VC-W170 relationship is consistent across different etiologies, though larger samples would be needed to detect potentially smaller between-group differences.

Hypothesis 5: Multiple Variables Uniquely Predict Vital Capacity and W170

Hypothesis Statement: When multiple predictor variables are examined simultaneously, vital capacity, training experience, and anthropometric factors will emerge as significant unique predictors of W170, while height and training experience will predict vital capacity, demonstrating that multiple factors contribute independently to these outcomes.

While bivariate correlations provide valuable information about pairwise relationships, multiple regression analysis allows for examination of the unique contributions of multiple variables simultaneously while controlling for the influence of other factors. The fifth hypothesis tests whether vital capacity, training experience, height, and other variables independently predict the outcomes of interest, providing insights into both modifiable (training) and non-modifiable (height) determinants of performance.

Table 6. Multiple Regression Analysis – Multiple Predictors of Vital Capacity and W170

Dependent Variable	Predictors	B	SE (B)	B	t	p	VIF
Vital Capacity (L)	Constant	-1.182	1.798	-	-0.657	0.535	-
	Height (cm)	0.039	0.015	0.488	2.600	0.041*	1.21
	Training Experience (months)	0.053	0.021	0.423	2.524	0.045*	1.16
	BMI (kg/m²)	-0.032	0.040	-0.154	-0.800	0.455	1.28
W170 (watts)	Constant	-92.48	41.52	-	-2.227	0.068	-
	Vital Capacity (L)	29.12	8.78	0.631	3.315	0.016*	2.09
	Training Experience (months)	2.23	0.84	0.389	2.655	0.038*	1.62
	Resting Heart Rate (bpm)	-1.28	0.65	-0.329	-1.969	0.096	1.41

Model Statistics: VC Model: $R^2 = 0.687$, Adjusted $R^2 = 0.499$, $F = 3.66$, $p = 0.061$; W170 Model: $R^2 = 0.748$, Adjusted $R^2 = 0.597$, $F = 4.94$, $p = 0.031$

Table 6 presents multiple regression analyses examining multiple predictors simultaneously, providing partial support for Hypothesis 5. For the vital capacity model, the overall regression explained 68.7% of the variance, though the omnibus F-test was marginally non-significant ($p = 0.061$), likely due to reduced statistical power from the small sample size. Within this model,

height emerged as a statistically significant predictor (β = 0.488, p = 0.041), with each centimeter increase in height associated with a 0.039 L increase in vital capacity. Training experience also showed a significant positive relationship (β = 0.423, p = 0.045), suggesting that longer volleyball training exposure contributes to improvements in respiratory function. BMI was not significantly related to vital capacity (p = 0.455). For the W170 model, the overall regression was statistically significant (F = 4.94, p = 0.031) and explained 74.8% of the variance. Vital capacity emerged as the strongest predictor (β = 0.631, p = 0.016), with each one-liter increase associated with a 29.12-watt increase in W170. Training experience also contributed significantly (β = 0.389, p = 0.038), with each additional month of training associated with a 2.23-watt increase. Resting heart rate showed a non-significant negative relationship (β = -0.329, p = 0.096), though the direction is consistent with cardiovascular fitness theory. All VIF values were below 2.5, indicating acceptable multicollinearity. These findings provide qualified support for Hypothesis 5.

Hypothesis 6: Training Experience and Assessment Timing Significantly Influence Vital Capacity and W170

Hypothesis Statement: Athletes with longer training experience will demonstrate higher vital capacity and W170 values, and performance measures will decline as time increases since the last training session, reflecting chronic training adaptations and acute detraining effects respectively.

The final hypothesis examines both chronic and acute training effects on the measured variables. Despite the low training frequency (twice monthly), it was hypothesized that accumulated training experience would be associated with superior physiological capacity, demonstrating that chronic adaptations can occur even under sub-optimal conditions. Additionally, given the extended periods between training sessions, it was expected that performance would decline as time elapsed since the last training bout, reflecting acute detraining effects.

Table 7. Analysis of Training Experience Duration and Temporal Effects on Performance

Training Characteristics	Category	N	VC (L) Mean ± SD	W170 (W) Mean ± SD	Performance Rating
Training Experience Duration	Short-term (8-12 months)	3	3.33 ± 0.38	111.7 ± 16.8	Moderate
	Mid-term (13-17 months)	3	3.72 ± 0.40	131.3 ± 14.2	Moderate-High

	Long-term (18-22 months)	3	4.07 ± 0.58	151.7 ± 17.5	High
	Linear Trend Statistics	-	r = 0.518*	r = 0.638*	F = 8.42, p = 0.022*
Days Since Last Training Session	2 days post-training	3	3.92 ± 0.55	143.3 ± 18.5	High
	3 days post-training	3	3.67 ± 0.45	128.0 ± 17.2	Moderate-High
	4 days post-training	3	3.53 ± 0.52	119.3 ± 25.8	Moderate
	Temporal Decline Statistics	-	r = -0.618*	r = -0.579*	p < 0.05
Disability Type × Training Experience Interaction	Lower Limb + Long Training	2	4.35 ± 0.21	161.5 ± 4.9	Very High
	Lower Limb + Short-Mid Training	3	3.82 ± 0.29	141.0 ± 9.5	High
	Other Disabilities + Long Training	1	3.75	135.0	Moderate-High
	Other Disabilities + Short-Mid Training	3	3.23 ± 0.25	102.3 ± 11.2	Low-Moderate
	Interaction Effect	-	F = 3.91, p = 0.089†	F = 4.28, p = 0.089†	-
Test Performance Consistency Metrics	High Consistency (CV < 10%)	3	4.12 ± 0.36	156.3 ± 9.8	Stable-High
	Moderate Consistency (CV 10-15%)	3	3.68 ± 0.39	129.7 ± 12.2	Stable-Moderate
	Low Consistency (CV > 15%)	3	3.32 ± 0.48	104.7 ± 17.2	Variable-Low
Monthly Training Volume Analysis	Average training hours/month	9	4.0 hours total	-	Sub-optimal frequency
	Correlation with VC	-	r = 0.504*	-	p < 0.05
	Correlation with W170	-	-	r = 0.618*	p < 0.05

Table 7 presents a comprehensive analysis of training patterns and temporal factors, providing strong support for Hypothesis 6. The analysis of training experience duration revealed a clear dose-response relationship. Athletes with long-term training experience (18-22 months) demonstrated substantially higher vital capacity (4.07 ± 0.58 L) and W170 (151.7 ± 17.5 watts)

compared to those with short-term experience of 8-12 months (VC: 3.33 ± 0.38 L; W170: 111.7 ± 16.8 watts), representing improvements of approximately 22% and 36% respectively. The mid-term training group showed intermediate values, creating a clear linear progression. Linear trend analysis confirmed statistically significant positive associations between training duration and both vital capacity ($r = 0.518$, $p < 0.05$) and W170 ($r = 0.638$, $p < 0.05$). These findings are particularly noteworthy given the remarkably low training frequency of only twice monthly, demonstrating that chronic physiological adaptations can occur even under sub-optimal training conditions. The temporal analysis examining days since the last training session revealed significant acute effects on performance. Participants tested two days after their last training session exhibited substantially higher performance (VC: 3.92 L; W170: 143.3 watts) compared to those tested three days post-training (VC: 3.67 L; W170: 128.0 watts) or four days post-training (VC: 3.53 L; W170: 119.3 watts), representing declines of approximately 10% in vital capacity and 17% in W170 from day 2 to day 4. The negative correlations between days since training and performance outcomes (VC: $r = -0.618$, $p < 0.05$; W170: $r = -0.579$, $p < 0.05$) confirm this pattern of temporal decline, suggesting that performance-enhancing effects of training sessions dissipate relatively quickly. The interaction analysis between disability type and training experience revealed that athletes with amputations who had accumulated long-term training experience achieved the highest performance levels (VC: 4.35 L; W170: 161.5 watts), substantially exceeding all other subgroups. In contrast, athletes with other disability types who had short or mid-term training experience showed the lowest values (VC: 3.23 L; W170: 102.3 watts). The interaction effects approached statistical significance ($p = 0.089$ for both variables), suggesting that training adaptations may be more pronounced in athletes with amputation. The analysis of test performance consistency revealed that athletes demonstrating high consistency (CV < 10%) also exhibited the highest absolute performance values (VC: 4.12 L; W170: 156.3 watts), whereas those with low consistency (CV > 15%) showed substantially lower performance (VC: 3.32 L; W170: 104.7 watts), suggesting that elite performers possess both superior physiological capacity and greater performance stability. These findings provide strong support for Hypothesis 6.

Discussion

The present study provides compelling evidence for a significant positive relationship between vital capacity and physical efficiency index among young volleyball players with disabilities, offering important insights into the physiological determinants of aerobic performance in this population. The strong association observed between respiratory function and physical work

capacity aligns with established physiological principles and extends existing knowledge from able-bodied populations to the context of adaptive sports.

The robust correlation between vital capacity and physical work capacity observed in this study confirms that respiratory function plays a central role in determining aerobic exercise capacity among athletes with disabilities. This finding is consistent with previous research in able-bodied athletes demonstrating that pulmonary function is closely linked to endurance performance capabilities. However, the particularly strong relationship observed in the current study suggests that respiratory capacity may be an even more critical determinant of performance for athletes with disabilities compared to their able-bodied counterparts. This heightened importance likely reflects the fact that many individuals with physical disabilities experience baseline respiratory limitations related to their primary impairments, making pulmonary function a more substantial constraining factor for exercise performance.

The physiological mechanisms underlying the relationship between vital capacity and physical work capacity are well-established in exercise physiology literature. Larger lung volumes provide greater alveolar surface area for gas exchange, facilitating more efficient oxygen uptake during exercise. Additionally, superior respiratory muscle strength, which contributes to higher vital capacity, reduces the metabolic cost of breathing during physical activity. This reduction in respiratory muscle work allows for greater blood flow allocation to working skeletal muscles, thereby enhancing overall exercise capacity. Furthermore, improved pulmonary function reduces the sensation of breathlessness during exertion, which can be a significant psychological and physiological barrier to sustained exercise performance. For athletes with disabilities, these mechanisms may be particularly salient given that respiratory limitations are often more pronounced in this population.

The finding that disability etiology did not significantly affect the VC-W170 relationship within this sample of lower extremity disabilities represents an important observation. Although participants had diverse impairments including hemiplegia, various amputation levels, poliomyelitis, and foot drop, the strong positive correlation between vital capacity and W170 held consistently across all disability types. This suggests that the fundamental physiological relationship between respiratory function and aerobic capacity transcends specific disability etiologies when considering lower extremity impairments. However, it should be noted that all participants in this study had lower extremity disabilities, and different patterns might emerge in athletes with upper extremity impairments or spinal cord injuries that more directly affect respiratory muscle function.

The evidence for training-related adaptations despite the remarkably low training frequency represents both an encouraging and cautionary finding. The positive associations between training experience and both vital capacity and physical work capacity indicate that chronic physiological improvements can occur even under sub-optimal training conditions. This suggests that the human body retains considerable adaptive plasticity even when training stimuli are infrequent and that athletes with disabilities can benefit from sustained participation in organized sport even when training opportunities are limited. However, the magnitude of adaptations observed, while meaningful, likely represents only a fraction of what could be achieved under more optimal training conditions with greater frequency and volume.

The temporal patterns observed in this study provide important insights into the dynamics of training adaptations and detraining in this population. The decline in performance measures as time elapsed since the last training session suggests that the extended recovery periods between training sessions may allow for partial reversal of training adaptations. This pattern is consistent with detraining research in able-bodied populations showing that physiological gains begin to diminish within days to weeks of reduced training stimulus. For athletes training only twice monthly, the week-long intervals between sessions may be sufficiently long to permit partial detraining, thereby limiting the accumulation and retention of adaptations over time. This finding underscores the importance of training frequency as a critical variable in program design and suggests that efforts to increase training opportunities could yield substantial benefits for athlete development.

The practical implications of these findings extend to multiple stakeholders in the adaptive sports community. For athletes and coaches, the results emphasize the value of respiratory function as both a performance determinant and a potential target for training interventions. Spirometric assessment can provide valuable feedback on training progress and help identify athletes who might benefit from targeted respiratory muscle training. For sports scientists and researchers, the findings highlight the need for disability-specific approaches to physiological assessment and training prescription, recognizing that the determinants of performance and the potential for adaptation may vary substantially across impairment types. For administrators and policymakers, the evidence for training-related improvements even under low-frequency conditions provides encouragement that adaptive sports programs can yield meaningful benefits, while the sub-optimal nature of the training frequency observed underscores the need for greater investment in resources and opportunities to support optimal athlete development.

The study's limitations warrant acknowledgment and consideration in interpreting the findings. The small sample size (n=9) constrains statistical power and limits the ability to detect smaller effects or conduct more sophisticated subgroup analyses. The cross-sectional design precludes definitive conclusions about causality, as the observed correlations could reflect not only the influence of vital capacity on work capacity but also common underlying factors or reverse causation. The heterogeneity of disability types within the sample, while reflecting the reality of many adaptive sports programs, complicates interpretation and limits the ability to draw disability-specific conclusions with confidence. The reliance on cycle ergometry, while providing standardized assessment of aerobic capacity, may not fully capture the sport-specific physiological demands of volleyball, which involves intermittent high-intensity activities and diverse movement patterns. Additionally, the sample was limited to lower extremity disabilities; findings may not generalize to athletes with spinal cord injuries or upper limb impairments that more directly affect respiratory function.

Future research should address these limitations through larger-scale studies employing longitudinal designs that can establish temporal precedence and causality. Intervention studies examining the effects of systematic respiratory muscle training on both pulmonary function and sport-specific performance would provide stronger evidence for the practical value of respiratory training interventions. Studies incorporating comprehensive physiological assessment batteries including respiratory muscle strength, additional pulmonary function indices, and maximal oxygen uptake would provide more complete characterization of the physiological factors determining performance. Research examining athletes training at various frequencies would help establish dose-response relationships and inform evidence-based recommendations for training prescription in adaptive sports settings. Additionally, studies including athletes with spinal cord injuries and upper limb disabilities would help determine whether the VC-W170 relationship varies across different disability categories.

In conclusion, this study demonstrates that vital capacity represents a significant and readily measurable predictor of physical work capacity in volleyball players with lower extremity disabilities, with the relationship holding consistently across different etiologies including hemiplegia, amputation, poliomyelitis, and foot drop. The findings support the integration of respiratory function assessment and training into adaptive volleyball programs. Despite limitations inherent in the small sample size and cross-sectional design, the study contributes valuable empirical evidence to the limited literature on physiological determinants of performance in adaptive sports and provides a

foundation for future investigations aimed at optimizing training approaches and enhancing performance outcomes for athletes with disabilities.

CONCLUSION

This study provides empirical evidence for a strong positive relationship between vital capacity and physical efficiency index (W170) among young volleyball players with lower extremity disabilities. The finding that respiratory function explains approximately 61.6% of the variance in physical work capacity highlights the importance of pulmonary function as a determinant of aerobic performance in this population. The regression equation developed in this study offers a practical tool for estimating work capacity from spirometric measurements, with potential applications in performance monitoring, talent identification, and training evaluation.

The finding that disability etiology (hemiplegia, amputation, poliomyelitis, foot drop) did not significantly affect the VC-W170 relationship within this sample suggests that the fundamental physiological association between respiratory function and aerobic capacity is consistent across different types of lower extremity impairments. However, the sample was limited to lower extremity disabilities, and different patterns may emerge in athletes with spinal cord injuries or upper limb disabilities that more directly affect respiratory muscle function.

Despite the remarkably low training frequency of approximately twice monthly, significant associations between training experience and both vital capacity and physical work capacity suggest that chronic physiological adaptations occur even under sub-optimal training conditions. However, the evidence for rapid performance decrements between training sessions and the substantial gap between current and recommended training frequencies highlight considerable opportunities for improving training prescription in adaptive volleyball programs. Efforts to increase training frequency, incorporate respiratory muscle training, and optimize recovery strategies could yield substantial benefits for athlete development and performance.

The findings of this study have important implications for multiple stakeholders in adaptive sports. For athletes with disabilities, the results emphasize the value of respiratory function training as a component of comprehensive conditioning programs and provide evidence that sustained training participation, even at limited frequencies, produces meaningful physiological improvements. For coaches and sports scientists, the study offers a validated assessment tool (the VC-W170 relationship) for monitoring training adaptations and highlights the importance of individualized training

prescription. For sports administrators and policymakers, the findings underscore the need for increased investment in adaptive sports programs to enable more frequent training opportunities and support optimal athlete development. For researchers, the study identifies important gaps in knowledge regarding physiological determinants of performance in adaptive sports and provides a foundation for future investigations.

In conclusion, vital capacity represents a significant and readily measurable predictor of physical work capacity in volleyball players with disabilities. Integration of spirometric assessment and respiratory training into adaptive volleyball programs has the potential to enhance performance evaluation, guide training prescription, and improve competitive outcomes for athletes with disabilities. Future research employing larger samples, longitudinal designs, inclusion of diverse disability types (particularly spinal cord injuries and upper limb impairments), and comprehensive physiological assessment will further elucidate the complex relationships between respiratory function, disability type, training factors, and performance in this important and growing athletic population.■

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