International Journal of Kinesiology & Sports Science
ISSN: 2202-946X
www.ijkss.aiac.org.au

Exploring the Learning Effect of the 6-minute Walk Test in Patients with Arterial Hypertension

Kaoutar Kabbadj*, Faiza Aziouaz, Abdelkader Jalil El Hangouche
Department of Physiology, Faculty of Medicine and Pharmacy of Tangier, Abdelmalek Essaadi University, Tangier, Morocco
Corresponding Author: Kaoutar Kabbadj, E-mail: kabbadj.kaoutar@etu.uae.ac.ma

ARTICLE INFO

Article history
Received: January 11, 2025
Revised: March 15, 2025
Accepted: March 25, 2025
Published: April 30, 2025
Volume: 13 Issue: 2

Conflicts of interest: The authors have no conflicts of interest to declare.
Funding: None

ABSTRACT

Background: The 6-minute walk test (6MWT) is widely used for assessing functional capacity in various clinical populations. However, the presence and extent of a learning effect in hypertensive patients remain insufficiently explored, particularly in Moroccan populations. **Objective:** This study aims to evaluate the learning effect in the 6MWT among hypertensive patients and to identify potential predictors influencing performance variation across repeated tests. **Methods:** This is a cross-sectional study in which 90 hypertensive patients completed three consecutive 6MWTs on the same day, with a 30-minute rest period between each trial. The distance walked was measured in meters during each test, while heart rate, blood pressure, and perceived exertion (Borg scale) were recorded before and after each test. Effect sizes were calculated to assess the magnitude of performance changes. Regression analyses were performed to explore potential predictors of the learning effect. **Results:** A significant improvement in walking distance was observed between the first and second trials (5.11% increase; Cohen's $d = -1.57$; $p < 0.001$), with no further significant changes between the second and third trials (Cohen's $d = 0.15$; $p = 0.152$). The Kruskal-Wallis test analysis revealed that baseline walking distance significantly influenced the learning effect ($p < 0.001$, $\eta^2 \approx 0.210$). Among all variables examined, baseline walking distance emerged as the only significant predictor, with participants who walked less than 300 meters during the first 6MWT trial exhibiting a markedly smaller improvement between trials compared to those with higher initial performance. No significant associations were found with other clinical or demographic factors (p for gender = 0.501; p for weight = 0.334; p for height = 0.387; p for BMI = 0.524; p for physical activity = 0.966). **Conclusion:** The results demonstrate a clear learning effect in hypertensive patients performing the 6MWT, stabilizing after the second trial. These findings underscore the importance of conducting at least two 6MWTs to accurately assess this population's functional capacity. Repeated trials in routine practice may help avoid underestimating patients' true exercise tolerance, thereby aiding more tailored rehabilitation planning.

Key words: Walk Test, Hypertension, Exercise Test, Physical Fitness

INTRODUCTION

The assessment of functional capacity is a key element in the management of chronic diseases, particularly in patients with cardiovascular conditions such as arterial hypertension. Functional capacity, refers to an individual's ability to perform physical activities in daily life, and provides essential insights into the disease's impact on patients' quality of life. In hypertensive patients, a decline in functional capacity can serve as an early indicator of more severe complications, including heart failure and other cardiovascular disorders.

Hypertension is a major public health problem with high prevalence worldwide. According to the World Health Organization (WHO), Africa recorded the highest prevalence, 27%, in 2021 (World Health Organization, 2023), underlining the urgency of addressing this condition. In Morocco, approximately 29.6% of the population was affected by hypertension in 2018 (Belayachi et al., 2024).

Arterial hypertension is not only a major risk factor for cardiovascular diseases but is also associated with anatomical and functional adjustments of the vascular system (R. de A. Ramos & Ferreira, 2014). These adjustments, such as vascular remodeling, can damage target organs, notably affecting the heart, kidneys, and brain (Mancia et al., 2007), ultimately impairing their function over time. Furthermore, musculoskeletal vessels also undergo structural changes (Hernández et al., 1999) that compromise overall physical performance, limiting functional capacity in hypertensive patients (Hajjar et al., 2007). Therefore, assessing this capacity is crucial to tailoring therapeutic interventions, optimizing physical rehabilitation, and improving overall clinical care.

Several tests are available to evaluate functional capacity, among which is the cardiopulmonary exercise test (CPET), which is considered the gold standard for functional performance assessment and cardiovascular risk identification

Published by Australian International Academic Centre PTY.LTD.

http://dx.doi.org/10.7575/aiac.ijkss.v.13n.2p.30

during exercise training. However, its dependence on complex equipment and the need for maximal effort can limit its feasibility for widespread use (Balady et al., 2010; Guazzi et al., 2012). As a result, simpler, less demanding alternatives have been developed for assessing functional capacity, predicting prognosis and monitoring the results of exercise training programs (Celli et al., 2016; Delbressine et al., 2025; Noonan & Dean, 2000; Spruit et al., 2012; Travensolo et al., 2020). Among these, the six-minute walk test (6MWT) is widely adopted tool, recognized for its simplicity, affordability, and clinical relevance (Bellet et al., 2012; Pepera et al., 2015; Purwowiyoto & Surya, 2021; R. A. Ramos et al., 2014; Sousa et al., 2015).

The 6MWT assesses exercise tolerance by requiring patients to walk as far as possible within six minutes on flat, straight, and unobstructed surface, usually a 30-meter corridor with clearly marked intervals. This test is particularly relevant as it closely mirrors patients' daily activities, such as walking or climbing stairs, and provides clinically meaningful information about overall functional capacity (Butland et al., 1982; Guyatt et al., 1985; Solway et al., 2001). Indeed, the distance covered during the test is often correlated with key physiological parameters, such as maximal oxygen consumption (VO2 max) (Troosters et al., 1999; Zielińska et al., 2013); a critical indicator of cardiorespiratory fitness. Consequently, the 6MWT has become an indispensable tool for evaluating functional capacity in patients with cardiovascular limitations, both in clinical research and routine practice.

However, a frequently overlooked aspect of the 6MWT is the learning effect, also known as the "training effect" or "practice effect" (Włoch et al., 2015); in which repeated trials improve performance due to increased familiarity rather than actual physiological progress. This effect is particularly pronounced in tests like the 6MWT, where walking speed is self-regulated by the patient. Several studies have investigated the learning effect associated with the 6-minute walk test (6MWT) across diverse populations. In individuals with chronic obstructive pulmonary disease (COPD), Sciurba et al. (2003) observed a significant increase in walking distance between the first and second tests, underscoring the influence of a learning effect and the necessity of repeating the test to obtain reliable results (Sciurba et al., 2003). Similarly, in a cardiac rehabilitation context, Hamilton and Haennel (2000) reported notable improvements across three successive 6MWTs, further suggesting the presence of a learning component in this population (Hamilton & Haennel, 2000). In healthy adults, Gibbons et al. (2001) conducted four 6MWTs and found that 86% of participants achieved their best performance after the first walk, with an average gain of 43 meters between the first and highest performance ($p < 0.003$) (Gibbons et al., 2001). Despite these findings, there is still no consensus regarding the magnitude of the learning effect (Włoch et al., 2015) or the number of trials needed to reach performance stabilization. Some studies report a plateau after the first two tests, while others observe continued improvements beyond the second repetition. Furthermore, very few studies have specifically examined this phenomenon in individuals with hypertension.

Studying the learning effect is essential when evaluating the functional capacity of hypertensive patients. Overlooking this effect may lead healthcare professionals to overestimate functional improvements following an intervention or rehabilitation period, mistakenly attributing gains to clinical progress rather than to a learning effect. The scarcity of data on the presence and extent of the learning effect in hypertensive populations highlights the urgent need for further investigation in this area, particularly to ensure accurate interpretation of test outcomes and effective clinical decision-making.

Therefore, this study aims to assess the presence and magnitude of the learning effect in hypertensive patients undergoing three repeated 6-minute walk tests (6MWTs). Specifically, we aim to determine the number of trials needed to reach performance stabilization and to assess whether individual characteristics (e.g., gender, BMI, physical activity level) influence this effect. We hypothesize that a learning effect will be present, that performance will stabilize after the second test, and that individual factors may influence the magnitude of this effect. This hypothesis is grounded in previous findings across various populations, where the greatest improvement in walking distance typically occurs between the first and second 6MWTs (Butland et al., 1982; Mungall & Hainsworth, 1979). The outcomes of this research may contribute to a more accurate clinical interpretation of 6MWT results and support the development of more effective rehabilitation strategies tailored to hypertensive patients.

METHODS

Participants and Study Design

This cross-sectional study was conducted from July 1 to October 18, 2024, in the Cardiology Department of the Provincial Hospital of Tetouan, Morocco. Participants were hypertensive patients referred for cardiology consultation and subsequently enrolled in a structured exercise reconditioning program.

A total of 105 individuals were initially recruited. Two were excluded due to medical contraindications, notably a resting diastolic blood pressure exceeding 100 mmHg, and three were unable to complete all three 6-minute walk tests (6MWT) due to time constraints. The final sample comprised 100 participants.

Eligible participants were adults aged 18 years or older with a confirmed diagnosis of hypertension. The diagnosis was established by a cardiologist, based on the average of three resting blood pressure measurements taken on separate visits, with systolic pressure ≥ 140 mmHg and/or diastolic pressure ≥ 90 mmHg. Additional confirmation was obtained through a review of the participant's medical history, including previous medical records and/or current antihypertensive treatment.

Exclusion criteria included the presence of cardiovascular disorders (such as unstable angina, recent myocardial infarction <6 weeks, systolic blood pressure > 180 mm Hg, and a diastolic blood pressure > 100 mm Hg), pulmonary conditions (e.g., chronic obstructive pulmonary disease, asthma requiring daily bronchodilators), neurological conditions (e.g., stroke sequelae, peripheral neuropathy, or Parkinson's disease.), and any musculoskeletal disorders impairing gait or requiring assistive devices, confirmed through musculoskeletal screening based on the GALS (Gait, Arms, Legs, Spine) assessment protocol. Additionally, participants who did not complete all three 6-minute walk tests were excluded.

Participation in the study was entirely voluntary. Prior to enrollment, all participants received detailed information regarding the study's objectives, procedures, and potential risks associated with the 6-minute walk test, including possible symptoms such as dyspnea, fatigue, or dizziness. They were explicitly instructed to stop the test immediately in case of any discomfort.

Procedure

Prior to testing, participants were instructed to fast and avoid caffeine for at least two hours and to refrain from smoking for four hours. Upon arrival, they underwent a clinical assessment that included medical history, physical examination, electrocardiography, echocardiography, and routine blood tests to confirm eligibility.

No warm-up session was performed before the six-minute walk tests (6MWTs) to avoid pre-test fatigue and allow for a more accurate observation of the natural learning effect across repeated trials. This approach ensures a more reliable comparison of performance improvements between tests.

The 6MWTs were conducted according to American Thoracic Society guidelines (ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories, 2002), on a flat, 30-meter indoor corridor marked every three meters. The corridor was quiet, with minimal pedestrian traffic. Ambient temperature was maintained between 22°C and 24°C with relative humidity between 40% and 60%. Lighting was uniform, and noise levels were kept low to avoid distractions. Each participant completed three separate 6MWTs on the same day, with a minimum 10-minute rest before the first test and 30-minute intervals between trials. This timing helped minimize fatigue while controlling for circadian rhythm fluctuations, as all tests were conducted at the same time of day.

Participants were instructed to walk as far as possible within six minutes at their usual pace, with the option to slow down or stop if necessary without interrupting the stopwatch. At each minute, they received standardized verbal encouragement, alternating between phrases such as, "Great job – 5 minutes left!" and "Keep it up – you have [X] minutes to go!". To standardize procedures and ensure transparency, the protocol was shown to study participants to familiarize them with the procedure prior to the test.

This protocol did not adopt a dual-task paradigm, despite its utility in assessing cognitive-motor interactions, because the primary objective was to isolate the pure motor learning effect associated with repeated physical performance. Adding a cognitive load might have confounded the interpretation of the walking distance as a sole indicator of learning.

Measurement

The primary outcome of this study was the total distance walked (in meters) during each 6-minute walk test (6MWT) trial. This variable was selected as the main indicator of the motor learning effect due to its simplicity, objectivity, and clinical relevance. The walked distance directly reflects submaximal exercise capacity, functional endurance, and the ability to sustain physical effort over time. It is also particularly sensitive to learning effects, making it a reliable indicator for evaluating improvements unrelated to physiological adaptation alone.

Although other physiological markers—such as oxygen consumption (VO_2), heart rate variability (HRV), or ventilatory efficiency (VE/VCO_2)—can theoretically reflect functional adaptation to effort or training, these were not included in the present study. Their measurement typically requires more sophisticated, expensive, and less portable equipment, which limits their feasibility in routine clinical practice, especially in resource-limited settings. In contrast, the 6MWT offers a non-invasive, cost-effective, and easily deployable alternative that remains widely used and endorsed by international clinical guidelines.

The 6MWT is a validated and widely used tool to assess submaximal aerobic capacity, particularly in individuals with chronic cardiovascular or respiratory diseases. Its strong criterion validity has been demonstrated by multiple studies showing significant correlations with VO_2 max, particularly in populations with heart failure, cancer, or advanced age (Rikli & Jones, 1998; Schmidt et al., 2013; Sousa et al., 2015; Uszko-Lencer et al., 2017). Moreover, the test is highly responsive to clinical changes following interventions such as rehabilitation (Bellet et al., 2012; Schmidt et al., 2013), reinforcing its utility for tracking progress over time. In terms of reliability, the 6MWT exhibits excellent test-retest reproducibility, with intraclass correlation coefficients (ICC) frequently exceeding 0.90 (Hanson et al., 2012; Macchiavelli et al., 2021; Pankoff et al., 2000).

Secondary outcomes in this study included systolic and diastolic blood pressure (SBP, DBP), heart rate (HR), and subjective fatigue:

Fatigue was assessed using the modified Borg Rating of Perceived Exertion Scale (0-10), a simple and validated tool widely recognized for its effectiveness in evaluating perceived fatigue (Arney et al., 2019; Cleland et al., 2016; Iellamo et al., 2014; PENKO et al., 2017). The scale ranges from 0, indicating no fatigue, to 10, representing maximal fatigue. Participants were asked to report their level of fatigue at the end of each walking trial. Prior to the test, clear instructions were provided to ensure participants understood how to accurately interpret and utilize the scale.

Heart rate was measured manually immediately before and after each test by palpating the radial pulse for 15 seconds and multiplying the result by four to obtain beats per minute (bpm). Although basic, this method is widely accepted in clinical practice and provides reliable results when performed by trained professionals (Mathis, 2023).

Blood pressure was measured immediately before and after each 6MWT trial using the OMRON M2 Basic automated device (model HEM-7121J-E; OMRON Corporation, Shiokoji Horikawa, Shimogyo-ku, Kyoto 600-8530, Japan). This device is validated according to international standards and demonstrates acceptable accuracy for clinical applications (Asmar et al., 2010; Topouchian et al., 2011). Measurements were performed on the participant's left arm while seated, with the cuff positioned at heart level, following a rest period of at least five minutes before the initial reading. To ensure accuracy and consistency in data collection, the device used for measuring blood pressure was calibrated weekly. Calibration for blood pressure was conducted by comparing readings with a reference device in the hospital.

Anthropometric data were also collected, including height, weight, and body mass index (BMI = weight in kg/height in m²).

All measurements were performed by qualified physiotherapist using the same equipment and standardized protocols throughout the study, under the supervision of the cardiologist.

Sample Size and Power Calculation

The sample size was calculated using G*Power software (version 3.1.9.7) assuming a moderate effect size (Cohen's $d = 0.3$), a statistical power of 0.80, and a significance level of 5%. The analysis indicated that a minimum of 71 participants was required to detect a significant learning effect on the distance covered during the 6MWT. To account for potential dropouts and to enhance the robustness of the findings, 105 participants were recruited.

Statistical Analysis

Prior to conducting the statistical analyses, outlier detection was performed by examining standardized residuals. Observations with residuals exceeding ±3 standard deviations were carefully reviewed to assess their potential impact on the model's outcomes. This procedure led to the identification of ten outliers, which were excluded from the final analysis, resulting in a final sample size of 90 participants. All statistical analyses were subsequently conducted on this adjusted sample. Regarding missing data, no missing values were detected across the variables under analysis. All participants provided complete data for all relevant variables, thus further ensuring the integrity and robustness of the conducted analyses.

Descriptive statistics were used to summarize participants' baseline characteristics and 6MWT performance. The normality of the data distribution was assessed using the Shapiro-Wilk test. Variables following a normal distribution were reported as mean ± standard deviation (SD). Logarithmic transformations were initially applied for variables not following a normal distribution, but these did not result in normality of the data. Consequently, non-parametric tests were used, and these variables were presented as median and interquartile range (IQR). Categorical variables were summarized as frequencies and percentages.

Paired-sample t-tests were conducted to compare the distances walked between 6MWT1 and 6MWT2 and between 6MWT2 and 6MWT3. For heart rate (HR) and Borg scores, repeated measures analysis of variance (ANOVA) was performed, provided the normality and sphericity assumptions were met. In cases of violated sphericity, the Greenhouse-Geisser correction was applied. Bonferroni-adjusted post-hoc tests were used to identify specific differences between trials. When the variables did not follow a normal distribution, the Friedman test was employed to assess differences between trials. If the Friedman test yielded a significant result, Bonferroni-corrected Wilcoxon signed-rank post-hoc tests were conducted to identify which trial pairs differed significantly.

To examine whether the potential learning effect is influenced by baseline walking performance, participants were stratified into three groups based on their initial 6MWT distance (<300 m, 300–450 m, and >450 m), using mortality-related thresholds as proposed in the literature (Rostagno et al., 2003; Zugck, 2000). The Kruskal-Wallis test was used to compare the learning effect across these performance groups. In case of a significant result, post-hoc comparisons were performed using the Dunn test for each pair of groups. Bonferroni correction was applied to the p-values of the post-hoc tests to adjust for the risk of Type I error, accounting for the number of comparisons made.

Furthermore, effect size calculations were performed to evaluate the magnitude of the observed effects across the statistical tests. Cohen's d was used for t-tests, η^2 (eta squared) for repeated measures ANOVA, η^2 for the Kruskal-Wallis test, and Kendall's W coefficient for the Friedman test. Effect sizes were computed for statistically significant results to emphasize the practical significance of the findings.

To explore determinants of the learning effect, we conducted univariate linear regressions for candidate predictors including age, sex, Weight (Kg), Height (cm), physical activity level, BMI and baseline 6MWT Distance <300 meters. Variables with a p-value <0.20 in univariate analyses were then entered into a multivariate linear regression model, allowing adjustment for potential confounders such as age and sex. Prior to regression, Pearson or Spearman correlation analyses were performed, depending on the data distribution, to examine the relationships between the dependent and independent variables, as well as between the independent variables themselves.

Statistical analyses were performed utilizing The Statistical Package for the Social Sciences version 26.0 (SPSS, Chicago, IL, USA) and G*Power (version 3.1), with significance established at $p < 0.05$.

RESULTS

This study included 90 participants, consisting of 43,3% men (n = 39) and 56,7% women (n = 51). The median age of the participants was 62(55-68) years, with no significant difference between genders (p = 0.094). Regarding body mass index (BMI), the overall mean was 27.23 ± 3.27 kg/m², with similar values between men and women (p = 0.710). Men had an average height of 175 cm (172-180) and weight of 85 kg (77–92), while women had an average height of 167 cm (165-170) and weight of 78kg (65-85); these

Table 1. Demographic and clinical characteristics of the study population

Variable		Men (n=39)			Women (n=51)			Total (n=90)	p-value women vs men
		Mean (SD)	Median (IQR)	N (%)	Mean (SD)	Median (IQR)	N (%)		
Age (y)			62 (55-68)			60 (53-64)		61 (54-66)	0.094
Height (cm)			175 (172-180)			167 (165-170)		170 (166-175)	<0.001
Weight (Kg)			85 (77-92)			78 (65-85)		80 (70-87)	<0.001
BMI (Body Mass Index)		27.23 (3.27)			26,98 (3.06)			27.09 (3,13)	0.710
Waist circumference (cm)			98 (95-105)			100 (86-107)		99.5 (89,5-106)	0.383
Heart rate		75.33 (10.06)			72,92 (9.45)			73.97 (9.73)	0.247
Systolic blood pressure (mm Hg)			132 (123-143)			132 (125-144)		132 (124-144)	0.549
Diastolic blood pressure (mm Hg)		80.54 (8.45)			80,86 (8.39)			80,72 (8.36)	0.857
Physical activity (3 times/week @ 30 minutes)	Inactive			28 (71.8%)			41 (80.4)	69 (76.7%)	0.339
	Active			11 (28.2%)			10 (19.6)	21 (23.3%)	

differences between genders were statistically significant ($p < 0.001$). Regarding physical activity levels, 76,7% of participants were classified as inactive, with no significant difference between men and women ($p = 0.339$). Table 1 provides an overview of the sociodemographic characteristics of the participants.

Figure 1 presents the distances covered during the three 6-Minute Walk Tests (6MWT). Statistical analysis was performed using the paired sample t-test. The results show a significant improvement between Test 1 and Test 2. The average distance covered in Test 1 (425.58 ± 75.83 meters) increased in Test 2 (447.32 ± 80.45 meters), with a difference of 21.74 meters, corresponding to a 5.11% increase ($p < 0.001$). This improvement is confirmed by a Cohen's effect size (d = -1.57), suggesting a large learning effect. In contrast, no significant difference was observed between Test 2 and Test 3. The distance covered in Test 3 (445.89 ± 79.71 meters) was nearly identical to that of Test 2, with a difference of -1.43 meters, representing a marginal decrease of -0.32% ($p = 0.152$). The effect size between these two tests is very small (Cohen's d = 0.15), indicating a minimal learning effect after Test 2.

This table presents the variations in heart rate (HR) and the Borg scale across the three tests. Resting heart rate (HR rest) exhibited no significant differences between the tests, with mean values remaining very similar: Test 1 (73.97 ± 9.73 bpm), Test 2 (74.04 ± 9.78 bpm), and Test 3 (74.08 ± 9.83 bpm), as determined by repeated measures

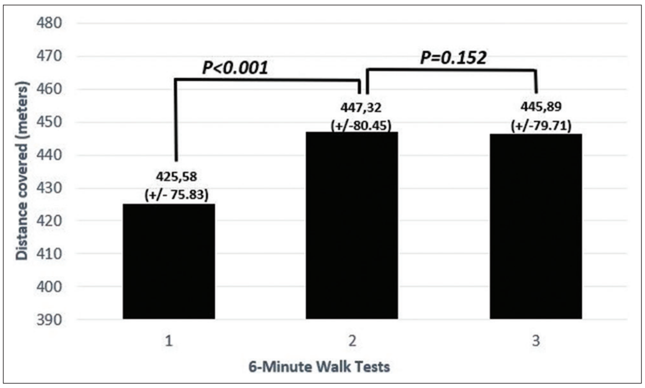

Figure 1. Distances walked during the three 6MWTs (1,2,3): Mean +- SD

ANOVA ($p = 0.760$). Similarly, heart rate at the end of exercise (HR end exercise) showed negligible variation between the tests, with no significant difference observed ($p = 0.130$), as indicated by the Friedman test. Finally, the Borg scale at the end of exercise (Borg end exercise) displayed no significant variation across the tests, with a p-value of 0.074, also confirmed by the Friedman test. These findings suggest that the observed learning effect in walking distance was not accompanied by significant physiological or perceptual adaptations. A detailed summary of HR and Borg scale variations is provided in Table 2.

Figure 2 illustrates the impact of the distance covered during the first test (baseline 6MWT) on the learning effect,

Table 2. Variations in heart rate and borg scale across tests 1, 2, and 3 of the 6-minute walk test

Measures	Test 1		Test2		Test 3		p-value
	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	
HR rest (bpm)	73.97 (9.73)		74.04 (9.78)		74.08 (9.83)		0.760
HR end exercise (bpm)		88 (81-99)		88 (81-99)		89 (82-99.25)	0.130
Borg end exercise		2 (2-3)		2 (2-3)		2 (2-3)	0.074

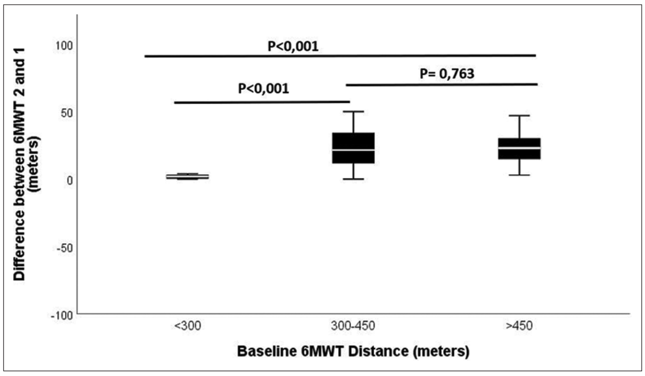

Figure 2. Effect of Baseline Six-Minute Walk Test (6MWT) Performance on the Difference Between Test 2 and Test 1

defined as the improvement in distance between Test 2 and Test 1. Statistical analysis was performed using the Kruskal-Wallis test, followed by Dunn's post-hoc tests to compare the differences in distance between Test 1 and Test 2 based on the baseline distance categories (<300, 300–450, >450 meters).

Participants in Group 1, with a baseline 6MWT distance of less than 300 meters (n = 8), showed a significantly lower learning effect (median of 2 meters) compared to those in Groups 2 (300–450 meters, n = 50) and 3 (>450 meters, n = 32) ($p < 0.005$). In contrast, no significant difference was observed between Groups 2 and 3, with their respective improvements being similar (median of 21.5 meters vs. 23 meters, $p = 0.763$). The effect size ($\eta^2 \approx 0.210$) suggests a moderate influence of baseline functional capacity on the learning effect.

The univariate analysis indicates that age significantly affects the learning effect, with a negative coefficient ($B = -0.394$, $p < 0.001$), suggesting that as age increases, the learning effect decreases. Additionally, the distance walked in the baseline 6-minute walk test (6MWT) of less than 300 meters is negatively associated with the learning effect ($B = -0.452$, $p < 0.001$), indicating that participants with a shorter baseline walking distance tend to show a reduced learning effect. However, the other variables, such as sex, weight, height, body mass index (BMI), and physical activity, do not show a statistically significant relationship with the learning effect.

In the multivariate analysis, which explained 23.4% of the variance in the learning effect ($R^2 = 0.234$), age lost its significance ($p = 0.070$), while baseline 6MWT distance of less than 300 meters remained a significant variable (standardized beta coefficient of -0.337, $p = 0.004$). These results suggest that baseline walking distance is an important predictor of the learning effect. Further details are presented in Table 3.

DISCUSSION

To the best of our knowledge, this study is among the first to investigate the learning effect across repeated trials of the 6MWT in hypertensive patients in Morocco. It provides new insights into its impact in this population and identifies key factors that may influence the interpretation of 6MWT performance in clinical practice.

This study indicates a significant learning effect in hypertensive patients during the 6MWT, with a notable improvement in walking distance between the first and second trials. These results are consistent with those of Ribeiro et al. (2011), who also reported an approximate 5% increase in walking distance between the first and second tests (Ribeiro et al., 2011).

Similar improvements have been documented in other patient populations. In individuals with pulmonary hypertension, a significant increase in walking distance was observed between the first and second tests, with a mean difference of 19 meters ($p < 0.001$) (Spencer et al., 2018). Similarly, among chronic heart failure patients, the average walking distance improved from 301 meters in the first test to 313 meters in the second ($p < 0.001$) (Adsett et al., 2011). Furthermore, Rodrigues et al. (2004) reported a significant improvement in individuals with chronic obstructive pulmonary disease (COPD), where the distance covered in the second trial (515 ± 82 meters) exceeded that of the first (480 ± 85 meters; $p < 0.05$) (Rodrigues et al., 2004). These consistencies may be explained by the comparable functional profiles frequently observed in individuals with cardiopulmonary diseases. Patients diagnosed with hypertension, heart failure, or chronic obstructive pulmonary disease often present similar degrees of exercise intolerance, reduced aerobic capacity, and deconditioning, in addition to psychological factors such as fear of exertion or low self-efficacy. These shared characteristics may predispose them to similar responses during repeated submaximal exercise testing.

Conversely, our research did not identify any significant difference between the second and third 6-minute walk tests. This result is in line with the findings of Eiser et al. in COPD patients(Eiser et al., 2003). This suggests that two tests may be sufficient to capture the maximum benefit from the learning effect.

The improvement in performance observed over successive trials of the 6MWT appears to be mainly due to

Table 3. Univariate and multivariate linear regression analyses identifying predictors of the learning effect in the 6MWT

Variables	Univariate analysis			Multivariate analysis (R^2= 0,234)		
	Standardized Beta	p-value	95% CI	Standardized Beta	p-value	95% CI
Age	**-0.394**	<0.001	-0.854 ; -0.289	**-0.207**	0.070	-0.625 ; 0.026
Sex	0.072	0.501	-3.862; 7.846			
Weight (Kg)	0.103	0.334	-0.132; 0.383			
Height (cm)	0.092	0.387	-0.251; 0.642			
BMI	0.068	0.524	-0.630; 1.228			
Physical activity	0.005	0.966	-6.729; 7.023			
Baseline 6MWT Distance <300 meters	**- 0.452**	<0.001	-30.924 ; -12.692	**-0.337**	0.004	- 27.090 ; -5.446

Standardized Beta: Standardized regression coefficient, indicating the relative effect of each independent variable; CI: Confidence Interval; R^2: Coefficient of Determination of the model; BMI: Body Mass Index; Variables with a p<0.2 in the univariate analysis were considered for the multivariable analysis. Bold values indicate statistical significance at p <0.05

neuromuscular and psychological adaptation mechanisms rather than an acute increase in physiological capacity. As participants repeat the test, they develop better motor coordination, adopt more efficient walking strategies, optimize effort management, and gain confidence. This hypothesis is supported by the absence of significant differences in heart rate and Borg scale scores between the three trials in our study, suggesting that perceived and physiological effort levels remained stable throughout the protocol. These results are consistent with those reported in previous studies (Kervio et al., 2003; Ribeiro et al., 2011; Spencer et al., 2018)., highlighting that the learning effect reflects behavioral adaptation and improved motor efficiency more than changes in cardiovascular capacity.

Clinically, this has important implications. If only a single 6MWT is performed, clinicians may underestimate the patient's true functional capacity, especially in those unfamiliar with the test. This could lead to suboptimal clinical decisions, such as under-prescribing exercise intensity or misinterpreting a patient's response to treatment. Accounting for the learning effect ensures a more accurate evaluation of physical performance and therapeutic progression, particularly in cardiac rehabilitation programs.

Furthermore, our analysis showed that the magnitude of the learning effect was dependent on baseline performance. Participants who walked less than 300 meters during the first test exhibited smaller improvements, possibly due to physical limitations or early achievement of maximal effort. In contrast, those with better baseline performance gained more from the learning effect, likely due to better physical reserves and reduced psychological constraints. These findings are in line with studies by Adsett et al. (2011) and Spencer et al. (2018), who observed minimal changes between tests in low-performing patients (Adsett et al., 2011; Spencer et al., 2018).

Interestingly, this observation contradicts findings in healthy individuals, where the learning effect was inversely related to baseline distance (G. Wu et al., 2003). In that population, a ceiling effect limited improvements beyond a certain distance, unless participants switched to jogging or running. This discrepancy is likely attributable to fundamental differences in population characteristics. Healthy adults generally possess superior cardiovascular fitness, greater muscular endurance, and fewer functional limitations compared to hypertensive patients, which reduces the potential for performance gains through repetition alone.

From a practical standpoint, our data support the use of two 6MWTs in clinical assessment, particularly for patients with moderate or good baseline performance. A single test might be sufficient for patients with severe limitations due to physiological constraints. Nevertheless, the standardization of testing procedures, including clear instructions and sufficient rest intervals, is essential for ensuring reliable and reproducible results. Clinicians are encouraged to interpret the test in light of individual capabilities and performance levels.

Regarding safety, no adverse events (severe chest pain, impaired coordination or dizziness, unbearable dyspnea or excessive fatigue) were observed during the 300 tests conducted. All sessions were supervised by trained physiotherapists from the cardiology department.

Study Strengths and Limitations

A key strength of this study lies in its focus on a relatively underexplored population—hypertensive patients—within the context of the learning effect in the 6MWT, particularly in a real-world clinical setting. The use of a repeated-measures design involving three trials allowed for a detailed examination of performance changes across successive tests, enabling the identification of the point at which performance plateaus. Moreover, the absence of adverse events across all trials reinforces the safety and feasibility of repeated testing in this population.

Nevertheless, several limitations should be acknowledged. Although the sample is relatively representative, its size may restrict the generalizability of the findings to a broader population. Future research could overcome this limitation by including a larger cohort to enhance the robustness and validity of the conclusions. In addition, the present study did not evaluate other potential variables that may affect 6MWT outcomes, such as diet, sleep quality and anxiety levels. Addressing these factors in future research would help clarify their impact on test performance.

CONCLUSION

This study provides valuable insights into the learning effect of the 6-minute walk test (6MWT) in Moroccan patients with hypertension. Our results reveal significant variations in distance covered across trials, particularly between the first and the second, underscoring the importance of familiarizing patients with the test to obtain accurate and trustworthy results.

The 6MWT remains a highly effective tool for evaluating functional capacity and exercise tolerance in individuals with chronic conditions like hypertension. To minimize the learning effect and better reflect true patient performance, conducting a minimum of two trials in a clinical environment is recommended.

Moreover, this research contributes to a deeper understanding of the 6MWT implementation within a Moroccan setting, potentially benefiting the precision and clarity of upcoming 6MWT assessments in Morocco. It emphasizes the significance of this test in evaluating and monitoring hypertensive patients, as well as the influence of this learning effect on result interpretation. Integrating these findings into clinical practice could potentially optimize functional capacity assessment practices and thus align therapeutic interventions more effectively with patients' specific needs.

ACKNOWLEDGEMENTS

The authors are thankful to all participants who contributed to this study.

AUTHOR CONTRIBUTIONS

K.K. and A.J.E.H. contributed to the conceptualization of the study. K.K. performed the literature search and data acquisition. The data and statistical analysis were carried out by K.K. and A.J.E.H. K.K., A.J.E.H., and F.A. were involved in the original draft preparation. The writing and editing of the manuscript were done by K.K., A.J.E.H., and F.A. The supervision of the project was provided by A.J.E.H.

ETHICAL APPROVAL

Written informed consent was obtained from each participant before inclusion. The research protocol was reviewed and agreed by a panel of experts belonging to the Research Committee of our University. The six-minute walk test, which is the subject of our study, is part of the standard initial assessment routinely carried out for patients consulting or hospitalized at Tetouan Hospital. The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki.

DATA AVAILABILITY STATEMENT

The datasets generated during this study are available from the corresponding author upon request.

REFERENCES

Adsett, J., Mullins, R., Hwang, R., Hogden, A., Gibson, E., Houlihan, K., Tuppin, M., Korczyk, D., Mallitt, K.-A., & Mudge, A. (2011). Repeat six-minute walk tests in patients with chronic heart failure: Are they clinically necessary? *European Journal of Cardiovascular Prevention & Rehabilitation*, *18*(4), 601606. https://doi.org/10.1177/1741826710389403

Arney, B. E., Glover, R., Fusco, A., Cortis, C., Koning, J. J. de, Erp, T. van, Jaime, S., Mikat, R. P., Porcari, J. P., & Foster, C. (2019). *Comparison of RPE (Rating of Perceived Exertion) Scales for Session RPE*. https://doi.org/10.1123/ijspp.2018-0637

Asmar, R., Khabouth, J., Topouchian, J., El Feghali, R., & Mattar, J. (2010). Validation of three automatic devices for self-measurement of blood pressure according to the International Protocol: The Omron M3 Intellisense (HEM-7051-E), the Omron M2 Compact (HEM 7102-E), and the Omron R3-I Plus (HEM 6022-E). *Blood Pressure Monitoring*, *15*(1), 49. https://doi.org/10.1097/MBP.0b013e3283354b11

ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories. (2002). ATS statement: Guidelines for the six-minute walk test. *American Journal of Respiratory and Critical Care Medicine*, *166*(1), 111117. https://doi.org/10.1164/ajrccm.166.1.at1102

Balady, G. J., Arena, R., Sietsema, K., Myers, J., Coke, L., Fletcher, G. F., Forman, D., Franklin, B., Guazzi, M., Gulati, M., Keteyian, S. J., Lavie, C. J., Macko, R., Mancini, D., Milani, R. V., Council on Epidemiology and Prevention, Council on Peripheral Vascular Disease, & Interdisciplinary Council on Quality of Care and Outcomes Research. (2010). Clinician's Guide to Cardiopulmonary Exercise Testing in Adults: A Scientific Statement From the American Heart Association. *Circulation*, *122*(2), 191225. https://doi.org/10.1161/CIR.0b013e3181e52e69

Belayachi, S., Boukhari, F. Z., Essayagh, F., Terkiba, O., Marc, I., Lambaki, A., Zohoun, A., Essayagh, M., Essayagh, T., & Essayagh, S. (2024). Uncontrolled blood pressure and its risk factors among hypertensive patients, Marrakech, Morocco. *Scientific Reports*, *14*(1), 2953. https://doi.org/10.1038/s41598-024-53115-y

Bellet, R. N., Adams, L., & Morris, N. R. (2012). The 6-minute walk test in outpatient cardiac rehabilitation: Validity, reliability and responsiveness—a systematic review. *Physiotherapy*, *98*(4), 277286. https://doi.org/10.1016/j.physio.2011.11.003

Butland, R. J., Pang, J., Gross, E. R., Woodcock, A. A., & Geddes, D. M. (1982). Two-, six-, and 12-minute walking tests in respiratory disease. *British Medical Journal (Clinical research ed.)*, *284*(6329), 16071608.

Celli, B., Tetzlaff, K., Criner, G., Polkey, M. I., Sciurba, F., Casaburi, R., Tal-Singer, R., Kawata, A., Merrill, D., & Rennard, S. (2016). The 6-Minute-Walk Distance Test as a Chronic Obstructive Pulmonary Disease Stratification Tool. Insights from the COPD Biomarker Qualification Consortium. *American Journal of Respiratory and*

Critical Care Medicine, *194*(12), 14831493. https://doi.org/10.1164/rccm.201508-1653OC

Cleland, B. T., Ingraham, B. A., Pitluck, M. C., Woo, D., & Ng, A. V. (2016). Reliability and Validity of Ratings of Perceived Exertion in Persons With Multiple Sclerosis. *Archives of Physical Medicine and Rehabilitation*, *97*(6), 974982. https://doi.org/10.1016/j.apmr.2016.01.013

Delbressine, J. M., Vaes, A. W., Stoop, W. A. M., Van Ranst, D., Spruit, M. A., & Van 'T Hul, A. (2025). Reproducibility of three 6-min walk tests in patients with COPD referred for pulmonary rehabilitation. *Respiratory Medicine*, *236*, 107884. https://doi.org/10.1016/j.rmed.2024.107884

Eiser, N., Willsher, D., & Doré, C. J. (2003). Reliability, repeatability and sensitivity to change of externally and self-paced walking tests in COPD patients. *Respiratory Medicine*, *97*(4), 407414. https://doi.org/10.1053/rmed.2002.1462

Gibbons, W. J., Fruchter, N., Sloan, S., & Levy, R. D. (2001). Reference Values for a Multiple Repetition 6-Minute Walk Test in Healthy Adults Older Than 20 Years. *Journal of Cardiopulmonary Rehabilitation and Prevention*, *21*(2), 87.

Guazzi, M., Adams, V., Conraads, V., Halle, M., Mezzani, A., Vanhees, L., Arena, R., Fletcher, G. F., Forman, D. E., Kitzman, D. W., Lavie, C. J., & Myers, J. (2012). Clinical Recommendations for Cardiopulmonary Exercise Testing Data Assessment in Specific Patient Populations. *Circulation*, *126*(18), 22612274. https://doi.org/10.1161/CIR.0b013e31826fb946

Guyatt, G. H., Sullivan, M. J., Thompson, P. J., & Fallen, E. L. (1985). The 6-minute walk: A new measure of exercise capacity in patients with chronic heart failure. *CAN MED ASSOC J*, *132*.

Hajjar, I., Lackland, D. T., Cupples, L. A., & Lipsitz, L. A. (2007). Association Between Concurrent and Remote Blood Pressure and Disability in Older Adults. *Hypertension*, *50*(6), 10261032. https://doi.org/10.1161/HYPERTENSIONAHA.107.097667

Hamilton, D. M., & Haennel, R. G. (2000). Validity and Reliability of the 6-Minute Walk Test in a Cardiac Rehabilitation Population. *Journal of Cardiopulmonary Rehabilitation and Prevention*, *20*(3), 156.

Hanson, L. C., McBurney, H., & Taylor, N. F. (2012). The retest reliability of the six-minute walk test in patients referred to a cardiac rehabilitation programme. *Physiotherapy Research International*, *17*(1), 5561. https://doi.org/10.1002/pri.513

Hernández, N., Torres, S. H., Finol, H. J., & Vera, O. (1999). Capillary changes in skeletal muscle of patients with essential hypertension. *The Anatomical Record*, *256*(4), 425432. https://doi.org/10.1002/(SICI)1097-0185(19991201)256:4<425:AID-AR9>3.0.CO;2-X

Iellamo, F., Manzi, V., Caminiti, G., Vitale, C., Massaro, M., Cerrito, A., Rosano, G., & Volterrani, M. (2014). Validation of rate of perceived exertion-based exercise training in patients with heart failure: Insights from autonomic nervous system adaptations. *International Journal of Cardiology*, *176*(2), 394398. https://doi.org/10.1016/j.ijcard.2014.07.076

Kervio, G., Carre, F., & Ville, N. S. (2003). Reliability and Intensity of the Six-Minute Walk Test in Healthy Elderly Subjects: *Medicine & Science in Sports & Exercise*, *35*(1), 169174. https://doi.org/10.1097/00005768-200301000-00025

Laboratories, A. C. on P. S. for C. P. F. (2002). ATS statement: Guidelines for the six-minute walk test. *Am J Respir Crit Care Med*, *166*, 111117.

Macchiavelli, A., Giffone, A., Ferrarello, F., & Paci, M. (2021). Reliability of the six-minute walk test in individuals with stroke: Systematic review and meta-analysis. *Neurological Sciences*, *42*(1), 8187. https://doi.org/10.1007/s10072-020-04829-0

Mancia, G., De Backer, G., Dominiczak, A., Cifkova, R., Fagard, R., Germano, G., Grassi, G., Heagerty, A. M., Kjeldsen, S. E., Laurent, S., Narkiewicz, K., Ruilope, L., Rynkiewicz, A., Schmieder, R. E., Boudier, H. A. J. S., Zanchetti, A., Vahanian, A., Camm, J., De Caterina, R.,… European Society of Cardiology. (2007). 2007 Guidelines for the Management of Arterial Hypertension: The Task Force for the Management of Arterial Hypertension of the European Society of Hypertension (ESH) and of the European Society of Cardiology (ESC). *Journal of Hypertension*, *25*(6), 11051187. https://doi.org/10.1097/HJH.0b013e3281fc975a

Mathis, A. (2023). Accurate Pulse Assessment by Radial Artery Palpation: A Pilot Study. *Honors Projects*. https://digitalcommons.iwu.edu/nursing_honproj/56

Mungall, I. P., & Hainsworth, R. (1979). Assessment of respiratory function in patients with chronic obstructive airways disease. *Thorax*, *34*(2), 254258.

Noonan, V., & Dean, E. (2000). Submaximal Exercise Testing: Clinical Application and Interpretation. *Physical Therapy*, *80*(8), 782807. https://doi.org/10.1093/ptj/80.8.782

Pankoff, B. A., Overend, T. J., Lucy, S. D., & White, K. P. (2000). Reliability of the six-minute walk test in people with fibromyalgia. *Arthritis Care & Research*, *13*(5), 291295. https://doi.org/10.1002/1529-0131(200010)13:5<291::AID-ANR8>3.0.CO;2-X

PENKO, A. L., BARKLEY, J. E., KOOP, M. M., & ALBERTS, J. L. (2017). Borg scale is valid for ratings of perceived exertion for individuals with Parkinson's disease. *International Journal of Exercise Science*, *10*(1), 7686.

Pepera, G., Ingle, L., & Sandercock, G. R. (2015). Predictors of the 6-minute walk test in patients with chronic heart failure. *British Journal of Cardiac Nursing*, *10*(9), 454549. https://doi.org/10.12968/bjca.2015.10.9.454

Purwowiyoto, S. L., & Surya, S. P. (2021). The Six Minute Walk Test as a Marker of Functional Capacity in Hypertensive Patients. *Jurnal Epidemiologi Kesehatan Komunitas*, *6*(2), 254260. https://doi.org/10.14710/jekk.v6i2.9742

Ramos, R. A., Guimarães, F. S., Cordovil, I., & De Sa Ferreira, A. (2014). The six-minute walk distance is a marker of hemodynamic-related functional capacity in hypertension: A case–control study. *Hypertension Research*, *37*(8), 746752. https://doi.org/10.1038/hr.2014.59

Ramos, R. de A., & Ferreira, A. de S. (2014). *Functional capacity in adults with hypertension as assessed by the six-minute walk distance test: Systematic review*.

Ribeiro, A., Younes, C., Mayer, D., Fréz, A. R., & Riedi, C. (2011). Teste de caminhada de seis minutos para avaliação de mulheres com fatores de risco cardiovascular. *Fisioterapia em Movimento*, *24*(4), 713719. https://doi.org/10.1590/S0103-51502011000400016

Rikli, R. E., & Jones, C. J. (1998). The Reliability and Validity of a 6-Minute Walk Test as a Measure of Physical Endurance in Older Adults. *Journal of Aging and Physical Activity*, *6*(4), 363375. https://doi.org/10.1123/japa.6.4.363

Rodrigues, S. L., Mendes, H. F. E., & Viegas, C. A. D. A. (2004). Teste de caminhada de seis minutos: Estudo do efeito do aprendizado em portadores de doença pulmonar obstrutiva crônica. *Jornal Brasileiro de Pneumologia*, *30*(2), 121125. https://doi.org/10.1590/S1806-37132004000200008

Rostagno, C., Olivo, G., Comeglio, M., Boddi, V., Banchelli, M., Galanti, G., & Gensini, G. F. (2003). Prognostic value of 6-minute walk corridor test in patients with mild to moderate heart failure: Comparison with other methods of functional evaluation. *European Journal of Heart Failure*, *5*(3), 247252. https://doi.org/10.1016/S1388-9842(02)00244-1

Schmidt, K., Vogt, L., Thiel, C., Jäger, E., & Banzer, W. (2013). Validity of the Six-Minute Walk Test in Cancer Patients. *International Journal of Sports Medicine*, *34*(07), 631636. https://doi.org/10.1055/s-0032-1323746

Sciurba, F., Criner, G. J., Lee, S. M., Mohsenifar, Z., Shade, D., Slivka, W., & Wise, R. A. (2003). Six-Minute Walk Distance in Chronic Obstructive Pulmonary Disease: Reproducibility and Effect of Walking Course Layout and Length. *American Journal of Respiratory and Critical Care Medicine*, *167*(11), 15221527. https://doi.org/10.1164/rccm.200203-166OC

Solway, S., Brooks, D., Lacasse, Y., & Thomas, S. (2001). A Qualitative Systematic Overview of the Measurement Properties of Functional Walk Tests Used in the Cardiorespiratory Domain. *Chest*, *119*(1), 256270. https://doi.org/10.1378/chest.119.1.256

Sousa, N., Furtado, H., Simão, R., Pereira, F., & Vilaça-Alves, J. (2015). Physical exercise and functional fitness in independently living vs institutionalized elderly women: A comparison of 60- to 79-year-old city dwellers. *Clinical Interventions in Aging*, 795. https://doi.org/10.2147/CIA.S80895

Spencer, L., Zafiropoulos, B., Denniss, W., Fowler, D., Alison, J., & Celermajer, D. (2018). Is there a learning effect when the 6-minute walk test is repeated in people with suspected pulmonary hypertension? *Chronic Respiratory Disease*, *15*(4), 339346. https://doi.org/10.1177/1479972317752762

Spruit, M. A., Polkey, M. I., Celli, B., Edwards, L. D., Watkins, M. L., Pinto-Plata, V., Vestbo, J., Calverley, P. M. A., Tal-Singer, R., Agusti, A., Coxson, H. O., Lomas, D. A., MacNee, W., Rennard, S., Silverman, E. K., Crim, C. C., Yates, J., & Wouters, E. F. M. (2012). Predicting Outcomes from 6-Minute Walk Distance in Chronic Obstructive Pulmonary Disease. *Journal of the American Medical Directors Association*, *13*(3), 291297. https://doi.org/10.1016/j.jamda.2011.06.009

Topouchian, J., Agnoletti,Davide, Blacher,Jacques, Youssef,Ahmed, Ibanez,Isabel, Khabouth,Jose, Khawaja,Salwa, Beaino,Layale, & and Asmar, R. (2011). Validation of four automatic devices for self-measurement of blood pressure according to the international protocol of the European Society of Hypertension. *Vascular Health and Risk Management*, *7*(null), 709717. https://doi.org/10.2147/VHRM.S27193

Travensolo, C. D. F., Arcuri, J. F., & Polito, M. D. (2020). Validity and reliability of the 6-min step test in individuals with coronary artery disease. *Physiotherapy Research International*, *25*(1), e1810. https://doi.org/10.1002/pri.1810

Troosters, T., Gosselink, R., & Decramer, M. (1999). Six minute walking distance in healthy elderly subjects. *European Respiratory Journal*, *14*(2), 270274. https://doi.org/10.1034/j.1399-3003.1999.14b06.x

Uszko-Lencer, N. H. M. K., Mesquita, R., Janssen, E., Werter, C., Brunner-La Rocca, H.-P., Pitta, F., Wouters, E. F. M., & Spruit, M. A. (2017). Reliability, construct validity and determinants of 6-minute walk test performance in patients with chronic heart failure. *International Journal of Cardiology*, *240*, 285290. https://doi.org/10.1016/j.ijcard.2017.02.109

Włoch, T., Mrozińska, A., Piliński, R., Śliwka, A., & Nowobilski, R. (2015). *Learning effect of the six-minute walk test in healthy young persons*.

World Health Organization [WHO]. (2023). *Hypertension*. https://www.who.int/news-room/fact-sheets/detail/hypertension

Wu, G., Sanderson, B., & Bittner, V. (2003). The 6-minute walk test: How important is the learning effect? *American Heart Journal*, *146*(1), 129133. https://doi.org/10.1016/S0002-8703(03)00119-4

Zielińska, D., Bellwon, J., Rynkiewicz, A., & Elkady, M. A. (2013). Prognostic Value of the Six-Minute Walk Test in Heart Failure Patients Undergoing Cardiac Surgery: A Literature Review. *Rehabilitation Research and Practice*, *2013*, 15. https://doi.org/10.1155/2013/965494

Zugck, C. (2000). Is the 6-minute walk test a reliable substitute for peak oxygen uptake in patients with dilated cardiomyopathy? *European Heart Journal*, *21*(7), 540549. https://doi.org/10.1053/euhj.1999.1861