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BRIEF REPORT

Prediction of Physiological Responses and Performance at Altitude Using the 6-Minute Walk Test in Normoxia and Hypoxia

Oliver R. Gibson, MSc; Alan J. Richardson, PhD; Mark Hayes, PhD; Ben Duncan, BSc; Neil S. Maxwell, PhD

From the Centre for Sport and Exercise Science and Medicine (SESAME), Welkin Human Performance Laboratories, University of Brighton, UK.

Objective.—The 6-minute walk test (6MWT) is a reliable and valid tool for determining an individual's functional capacity, and has been used to predict summit success. The primary aim of the study was to evaluate whether a 6MWT in normobaric hypoxia could predict physiological responses and exercise performance at altitude. The secondary aim was to determine construct validity of the 6MWT for monitoring acclimatization to 3400 m (Cuzco, Peru).

Methods.—Twenty-nine participants performed six 6MWTs in four conditions: normoxic outdoor (NO), normoxic treadmill (NT), and hypoxic treadmill (HT) were each performed once; and hypoxic outdoor (HO) was performed three times, at 42 hours (HO1), 138 hours (HO2), and 210 hours (HO3) after arrival at Cuzco.

Results.—One-way analysis of variance revealed no difference ($P > .05$) between NO and HO1 for 6MWT distance. HT and HO protocols were comparable for the measurement of delta heart rate (HR) and post-test peripheral oxygen saturation (%Spo_2; $P > .05$). Acclimatization was evidenced by reductions ($P < .05$) in resting HR and respiratory rate (RR) between HO1, HO2, and HO3, and preservation of Spo_2 between HO1 and HO2. Postexercise HR and RR were not different ($P > .05$) with acclimatization. The duration to ascend to 4215 m on a trek was moderately correlated ($P < .05$) to HR during the trek and the 6MWT distance during HT; no other physiological markers predicted performance.

Conclusions.—The 6MWT is a simple, time-efficient tool for predicting physiological responses to simulated and actual altitude, which are comparable. The 6MWT is effective at monitoring elements of acclimatization to moderate altitude.

Key words: 6-minute walk test, altitude sickness, hypoxia, mountaineering

Introduction

Acute altitude exposure can lead to acute mountain sickness (AMS), with 48% to 51% of travelers to Cuzco, Peru, reporting symptoms.[1,2] Prolonged exposures at elevations greater than 1500 m are sufficient to induce AMS, which is on the high altitude illness spectrum with potential to progress to high altitude pulmonary edema and high altitude cerebral edema if untreated.[3,4] Physical exertion increases AMS, with increased physiological strain placed on cardiac, pulmonary, vascular, and muscular systems. The development of a simple and efficient test for monitoring changes in physiological responses and symptoms of AMS before travel and at altitude[5] would be beneficial in aiding the identification of individuals at risk of altitude illness.

The 6-minute walk test (6MWT) has been widely used in clinical and research settings to determine and monitor exercise capacity. Performance can be linked to rates of ascent, and physiological responses to exercise at altitude can be determined.[5,6] Previously, a peripheral oxygen saturation (Spo_2) greater than 75% after a 6MWT at a 4365-m base camp was demonstrated to be a useful screening test for predicting the outcome of successfully reaching the summit of Aconcagua (6962 m).[5] More recently, however, Daniels[6] concluded that Spo_2 and 6MWT performance were unlikely to be effective in predicting summit success on Kilimanjaro (5895 m). If the data demonstrate a good relationship between

Corresponding author: Oliver R. Gibson, MSc, School of Sport and Service Management, Welkin Laboratories, University of Brighton, Eastbourne, BN20 7SR United Kingdom (e-mail: o.r.gibson@brighton.ac.uk).

performances in the 6MWT and physiological responses to altitude and summit success, then the 6MWT may be a useful test.

The primary aim of the study was to evaluate whether a 6MWT in normobaric hypoxia could predict physiological responses and exercise performance at altitude. Second, we aimed to determine construct validity of the 6MWT for monitoring acclimatization to 3400 m (Cuzco, Peru).

Method

Twenty-nine (14 female) healthy participants (age, 22.2 ± 5.4 years, with no prior history of AMS and no exposure to simulated or actual altitude for 8 weeks before commencement of study; see Table 1 for descriptive data on day of test) volunteered to participate in an 18-day project in Eastbourne, UK, and Cuzco, Peru. After a full description of experimental procedures, the protocol was approved by the University of Brighton ethics committee. All participants completed medical questionnaires and provided written informed consent following the principles outlined by the Declaration of Helsinki of 1975, as revised in 2008.

PRELIMINARY TESTING

Anthropometric data were collected for height (cm; Detecto Physicians Scales; Cranlea & Co, Birmingham, UK), body mass (kg; Adam GFK 150, Adam Equipment Co Ltd, Danbury, CT), and percentage body fat obtained after multifrequency bioelectrical impedance analysis (Xitron 4000, San Diego, CA) after 20 minutes of supine rest. Hydration status was confirmed in accordance with established guidelines to reduce the potential for fluid-dependent changes in AMS.[7,8]

6-MINUTE WALK TESTING

Each participant completed testing on six occasions at which a first familiarization and then experimental 6MWT were performed to permit habituation to the method and environment, and to ensure reliability on each day.[9] Ten minutes of seated rest was provided between familiarization and experimental trials. Only data from the experimental 6MWT were analyzed. Participants performed a normoxic treadmill (NT) test, normoxic outdoor (NO) test, and a hypoxic treadmill test (HT) within a 7-day period (all at sea level, 760 mm Hg) separated with 24 hours of rest. After arrival in Cuzco, Peru (altitude approximately 3400 m, 460 mm Hg), 3 additional hypoxic outdoor tests were performed at 42 (HO1), 138 (HO2), and 210 (HO3) hours. Participants performed all 6MWTs in identical athletic attire between

Table 1. Mean (95% CI) participant and environment data for normoxic treadmill (NT), normoxic outdoor (NO), and hypoxic treadmill (HT) 6-minute walk tests, and hypoxic outdoor 6-minute walk tests performed 42 hours (HO1), 138 hours (HO2), and 210 hours (HO3) after arrival at 3400 m

Variable	*NT (n = 29)*	*NO (n = 28)*	*HT (n = 29)*	*HO1 (n = 27)*	*HO2 (n = 26)*	*HO3 (n = 27)*
Body mass (kg)	71.5 (66.2–76.9)[a,d]	71.8 (66.5–77.1)[b,d]	71.3 (66.5–77.1)[a]	70.7 (65.6–75.9)[a,c]	69.6 (64.5–74.7)[a,b,c,d]	69.6 (64.5–74.7)[a,b,c,d]
Height (cm)	173.5 (169.5–177.4)	173.5 (169.5–177.4)	173.5 (169.5–177.4)	173.5 (169.5–177.4)	173.5 (169.5–177.4)	173.5 (169.5–177.4)
BMI (kg/m^2)	23.9 (22.4–25.5)[d]	24.0 (22.5–25.5)[b,d]	23.9 (22.3–25.4)[a]	22.6 (20.0–25.2)[a,b,c]	23.2 (21.8–24.7)[a,b,c]	23.2 (21.8–24.7)[a,b,c]
Body fat (%)	20.7 (17.7–23.6)	20.7 (17.7–23.6)	20.7 (16.1–22.6)	19.4 (17.7–23.6)	20.7 (17.7–23.6)	20.7 (17.7–23.6)
Temperature (°C)	20.6 (20.2–21.0)[a,d,e]	14.7 (14.1–15.4)[b,c,d,e]	20.3 (20.0–20.7)[a,d,e]	24.2 (24.2–24.2)[a,b,c,e]	27.0 (27.0–27.0)[a,b,c,d]	21.9 (21.9–21.9)[a,b,c,d,e]
Relative humidity (%)	32.5 (30.4–34.7)[d]	31.7 (31.1–32.2)[d]	33.6 (29.5–37.7)	37.2 (37.2–37.2)[a,c,e]	31.0 (31.0–31.0)[d]	38.8 (38.8–38.8)[a,c,d,e]
Wind speed (km/h)	0.0 (0.0–0.0)[a,b,d]	3.0 (2.9–3.0)[b,c,d,e]	0.0 (0.0–0.0)[a,b,d]	0.2 (0.2–0.2)[a,c,e]	0.0 (0.0–0.0)[a,b,d]	2.6 (2.6–2.6)[a,b,c,d,e]

[a] Denotes difference from NO ($P < .05$).
[b] Denotes difference from HT ($P < .05$).
[c] enotes difference from NT ($P < .05$).
[d] enotes difference from HO1 ($P < .05$).
[e] enotes difference from HO2 ($P < .05$).