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Efficacy of a light-weight ventilation vest to reduce heat strain and enhance endurance performance while treadmill walking in the heat

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Objective: To examine the effects of a light-weight ventilation vest on maximum endurance and physiological and subjective responses during strenuous physical activity in a hot environment.

Background: Heat strain is a major cause of reduced physical performance and heat related illness. Heat strain is a common problem when working in hot conditions, especially when wearing protective clothing. It is well documented that high ambient temperatures have a detrimental effect on physical capacity and well-being and negatively influence productive efficiency. In this study we evaluated the capability of a light-weight ventilation vest to reduce heat strain during a step-wise treadmill-walking-test in hot conditions. It was hypothesized that the ventilated vest would reduce heat stress and enhance endurance.

Methods: Nineteen male subjects (27.9 ± 6.3 years) completed two strenuous treadmill walking tests in a hot environment (30 °C, average relative humidity 48%), wearing fire fighter´s protective clothing. The tests were separated by at least two days. One test was performed with a ventilated vest ([ventilationVest]®), Entrak, Wendelstein, Germany) under the protective clothing, one test without. After randomization half of the subjects performed the first test with a ventilated vest, the other half without. The exercise protocol consisted of a stepwise treadmill-walking-test (Uno Fitness LTX 5 Pro, Bonn, Germany) till volitional fatigue. Starting with a velocity of 5 km/h the speed was increased by 0.5 km/h every 10 min. The slope was kept constant at 15%. Every 10 minutes a break of two minutes was conducted for performing measurements, leading to an interval-like loading, characterized by a loading-period of 8 minutes followed by a break of two minutes. Primary endpoints were maximum endurance time, maximum power output, maximum oxygen uptake (Viasys Oxycon mobile, Conshohocken, PA, USA) and physical work capacity. Secondary endpoints were heart rate and the body temperature of different regions. The following body temperature measurements were conducted at the end of each 10 min interval: rectal, axillary (Dermotherm Rapid, Uebe medical GmbH, Wertheim, Germany), tympanic (ThermoScan, Braun GmbH, Kronberg, Germany), and skin (at the chest under the pulse belt; designed in our department).
In addition subjects rated their thermal sensation and thermal comfort every 10 min. According to the Borg scale the rating scale for thermal sensation ranged from 6 (neutral) to 20 (very hot). The thermal comfort rating scale ranged from 0 to 3 (0 = clearly acceptable; 1 = just acceptable; 2 = just not acceptable; 3 = clearly not acceptable).
To determine the effect of the [ventilationVest]®, comparision of the mean values of the tests without and with [ventilationVest]® were conducted using a dependent samples t-tests for normally distributed variables. Otherwise a Wilcoxon test was performed. A 5% probability level was considered significant. For statistical analysis SPSS Version 14.0 was used.

Results: Table 1 lists the maximum endurance time, maximum oxygen uptake, maximum power output and physical work capacity. The maximum endurance time was extended by 6.8 minutes (17.3%) wearing the [ventilationVest]® ($p<0.001$). The maximum oxygen uptake was 8.5% higher in the test with [ventilationVest]® compared to without ($p<0.005$). Power output and physical work capacity increased by 8.6% and 13.6%, respectively, when wearing the [ventilationVest]®.

	without Vest	with Vest	Difference [%]	p-value
Max. endurance time [min]	39.4 ± 9.6	46.2 ± 10.3	17.3	0.001
$VO2_{max}$ [ml/kg/min]	42.5 ± 5.5	46.1 ± 4.6	8.5	0.003
$power_{max}$ [Watt]	277.0 ± 34.5	300.7 ± 36.5	8.6	0.000
$work_{tot}$ [kJ]	521.0 ± 163.8	591.7 ± 164.3	13.6	0.000

Tab. 1: maximum endurance time, oxygen uptake, power and physical work capacity with and without [ventilationVest]®.

Figures 1 - 3 show the heart rate, the temperature of different body locations, and the subjective heat sensation and acceptability at the end of the 10 min intervals during the treadmill-walking-test with and without [ventilationVest]®. Significant differences are marked by asterisks. Starting from 20 min heart rate was significantly lower with than without [ventilationVest]®. In the average during loading the heart rate was 5.2 beats/min lower using the [ventilationVest]®. Further the recovery of heart rate, calculated as the difference of the maximum heart rate during loading and the minimum heart rate during the following break, increased significantly (19%). Concerning body temperature, the axillary temperature was significantly lower after 20 and 40 minutes. Skin temperature was significantly lower at each measurement point, except baseline. Tympanic temperature was significantly lower after 40 min. Heat sensation was significantly lower with [ventilationVest]® between 0 and 30 minutes. Heat acceptability was significantly lower between 30 and 40 min.

Conclusions: In conclusion the [ventilationVest]® increased the maximum endurance time by 17%, maximum work capacity by 13,6% and reduced physiological and subjective strain responses during intensive physical activity in the heat. The results suggest that wearing the [ventilationVest]® may extend effective work time.

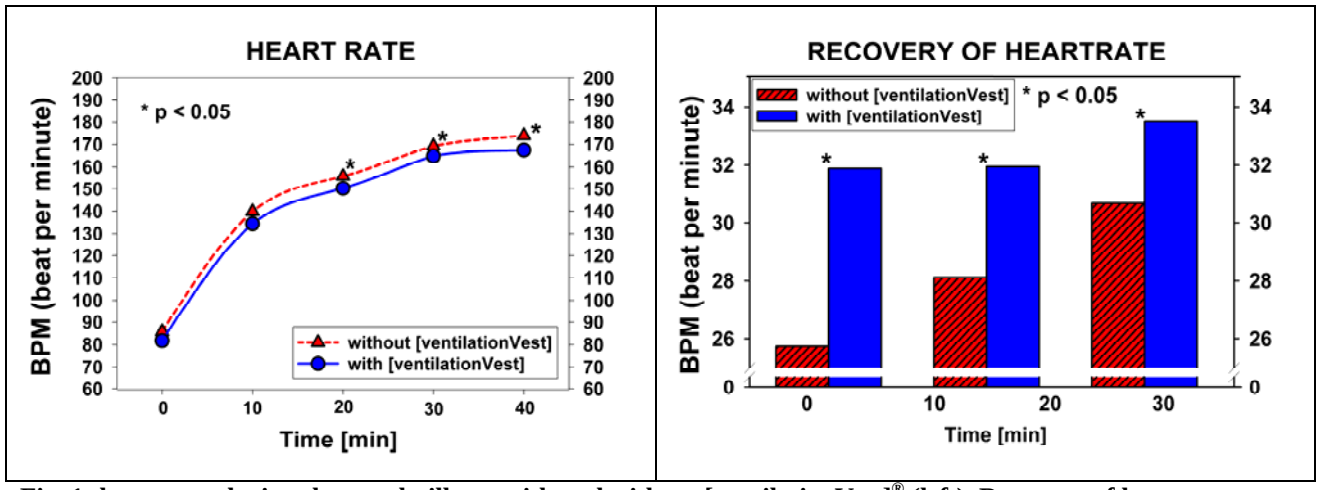

Fig. 1: heart rate during the treadmill test with and without [ventilationVest]® (left). Recovery of heart rate with and without [ventilationVest]® right (calculated as the difference of the maximum heart rate during loading and the minimum heart rate during the following break).

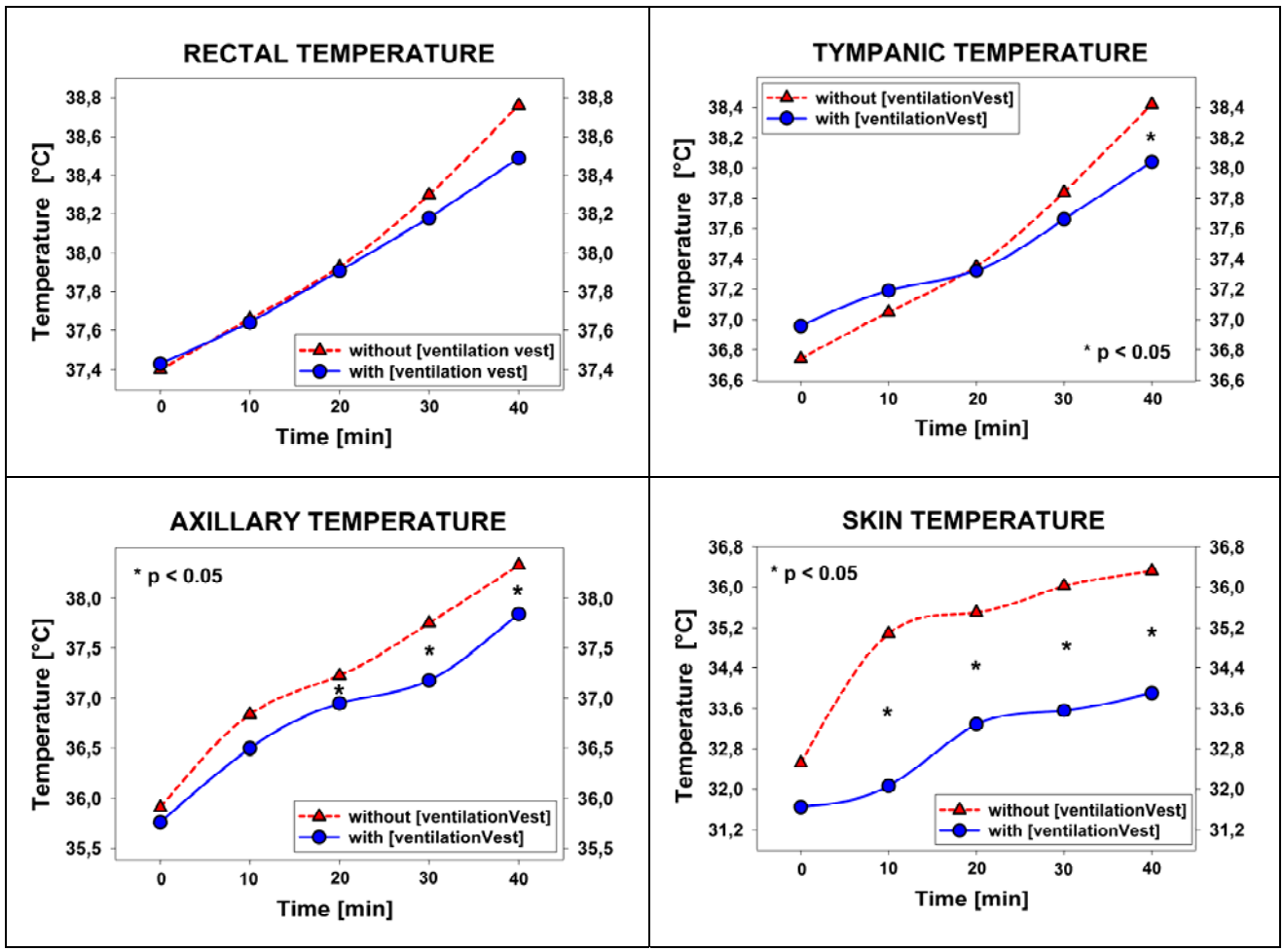

Fig. 2: temperature at different body locations during the treadmill test with and without [ventilationVest]®.

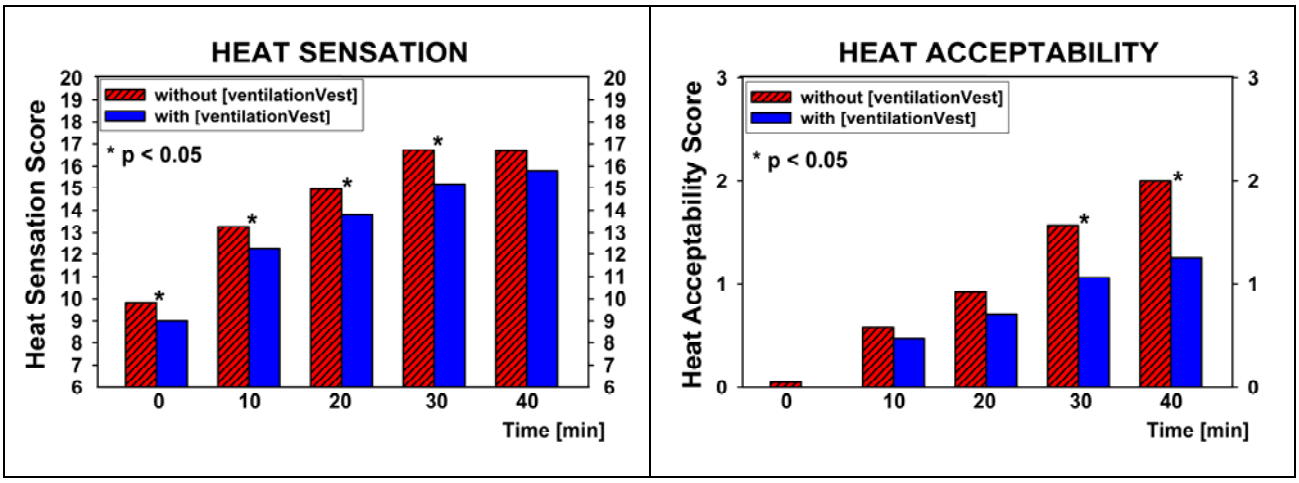

Fig. 3: heat sensation and heat acceptability at each 10 min interval during the treadmill test with and without [ventilationVest]®.