

Maximum and Resting Heart Rate in Treadmill and Deep-Water Running in Male International Volleyball Players

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The aim of the study was to compare the physiological responses to deep water running (DWR) compared with treadmill running (TMR) by male international volleyball players. We compared the maximum, recovery, and resting heart rates, maximum blood lactate and ratings of perceived exertion between DWR and standard laboratory TMR tests. The maximum heart rate (HR_{max}) was 14.9 bpm lower in water than on land ($p = .001$, 95% confidence interval, 7.74–22.06). The recovery HR at three minutes was 16.4 bpm lower in water ($p = .012$, CI 95%, 4.57–28.23). The differences in the maximum HR and the three-minute recovery HR likely reflected a cardiovascular response mediated by immersion in water. The maximum blood lactate and the ratings of perceived exertion suggested that both tests were undertaken at the same effort levels. Before prescribing exercise intensity a water specific test should be performed.

Maximum effort tests are mainly aimed at measuring levels of maximal and submaximal physiological responses to exercise. These measurements include such variables as oxygen consumption, heart rate, blood lactate, and rating of perceived exertion. The physiological parameters should be measured objectively to obtain control measurements before extrapolating these to physical training or therapy parameters (e.g., speed, space, time, power, rhythm, cadence; González-Iturri, 1999). Therapeutic exercise in hydrotherapy pools is currently recommended as part of the consensus guidelines for physiotherapists (Larsen, Pryce, & Harrison, 2002) as well as being used by experts in recovery from sporting injuries or in the maintenance of physical fitness during the presence of a lesion, especially among high-performance athletes (Butts, Tucker, & Christine, 1991; Cuesta-Vargas & Guillen-Romero, 2005; Eystone, Fellingham, George, & Fisher, 1993; Takeshima, Nakata, Kobayashi, Tanaka, & Pollock, 1997).

Important differences exist in the cardiovascular response to exercise in water compared with exercising on land. These include a decrease in maximum heart

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rate when swimming compared with running (McArdle, Margel, Delio, Toner, & Chase, 1978) cycling in the water versus running on land (Wilmore & Costill, 2004), deep water running versus cycling in water (Eystone, Fellingham, George, & Fisher, 1993), deep water running versus running on land (Christie et al., 1990) and walking on land versus walking in water (Whitley & Schoene, 1987). Water temperature and depth are also important factors when comparing the difficulty between different activities in water (Gleim & Nicholas, 1989). Other differences involve increased systolic volume (Sheldahl, Tristani, Clifford, Hughes, Sobocinski, & Morris, 1987; Wilmore & Costill, 2004), reflex bradycardia (Natelson, Nary, Curtis, & Creighton, 1983; Sheldahl et al., 1987), decreased metabolic levels due to decreased use of tonic muscles (Butts, Tucker, & Christine, 1991), increased metabolic expenditure required by thermoregulation (Allison & Reger, 1998; Avellini, Shapiro, & Pandolf, 1983; Gleim & Nicholas, 1989), altered respiratory rate due to the influence of the hydrostatic pressure (Begin et al., 1976), and improved venous return (Takeshima, Nakata, Kobayashi, Tanaka, & Pollock, 1997; Butts, Tucker, & Christine, 1991).

Recent studies provide results on metabolic costs that were similar between submaximal test on aquatic and land treadmills at running speeds of 174–228 m/min (Rutledge, Silver, Browder & Dolny, 2007). Also this research group studied metabolic cost of addition of jet resistance in aquatic treadmill and they found a significant difference in similar increase to change speed of 27.8–54.6 m/min (Rutledge et al., 2007).

The peak cardiorespiratory response during aquatic treadmill exercise has been analyzed for determined the reliability and has been found an ICC very strong (0.90–0.99; Silvers & Dolny, 2007). We have not found reliability studies of DWR test.

Deep water running (DWR) exercises have not been sufficiently studied to determine all the outcomes related to these factors in high-performance athletes. We cannot yet reliably and safely prescribe water exercise for rehabilitation of athletes only based in treadmill land tester. In view of evidence on the physiological responses in water exercise in this specific sample, the aim of the current study was to compare maximal cardiovascular response between running on treadmill versus deep water running exercises in high-performance athletes.

Method

Participants

The study involved 10 Caucasian male volleyball players from an international competitive team (Table 1). They undertook a minimum of 20 hr training per week. They all had a minimum of 10 years experience of training over 15 hr per week. Subjects were excluded if they were injured at the time of the study. During the experimental phase, the subjects were staying at a high performance center in preparation for an international competitive event. Ethical principles were adhered to by obtaining informed consent and the data were grouped to guarantee anonymity. The study was approved by the Ethics Committee of the Faculty of Medicine, Malaga University.

Table 1 Subjects Description

EDAD	PESO	TALLA
26	88,3	193,2
23	93	197
26	89,5	185,5
24	99,4	205,5
24	86,6	188,4
29	83	197
25	107	200,2
31	76	186
27	89,1	189,7
27	85,1	206,8
23	88,7	199,7
24	91,7	198,4
26	89,8	195,6
2,401	7,833	7,134

Procedures

The tests were performed in a human performance laboratory with a PowerJog J series treadmill adjustable for inclination and speed. The heart rate was recorded electrocardiographically with a SANRO model Kenz ECG-107. An automated lancet was used for micropuncture, and measurement of lactic acid in blood was made with a Lactate Pro LT-1710 automated analyzer with a reliability $r = .98$ (Pyne, Boston, Martin, & Logan, 2000). The tests in water were undertaken in a heated swimming pool measuring 25×12.5 m with a depth of 2.00 m. The water temperature was 28°C , the ambient air temperature was 30°C , and the relative humidity was 90%. The flotation belts (Burbujita, Aqua-jogger models) were attached to Thera-band tubular elastic bands fixed to the edge of the pool. The heart rate was monitored with a Polar 610i pulse-monitor. A Quartz QwikTime metronome, with the volume amplified, was used to set the cadence. All subjects were tested in the same order, first on the TMR test and then on the DWR test.

TMR Test. All participants performed a running protocol starting at 5 kph, which was undertaken for five minutes as an adaptation period. The test then began with a constant slope of 1% and increased in speed of 1 kph every two minutes until the participant reached physiological or volitional fatigue. This testing protocol was selected according to the consensus agreement of FIMS (FIMS 2005).

DWR Test. After a 48-hr recovery period, the participants underwent a single familiarization session of the water exercise protocol. The participants were shown the correct technique for water running (Huey & Forster, 1993), modified by

Cuesta-Vargas and Guillen-Romero (2005). The water running trials were supervised by an independent, trained technician. An acceptable stride was one in which the leading leg maintained at least 90 degrees of knee flexion through the swing phase and the trail leg extended at least to the vertical line (Figure 1). Compliance with this coordination pattern was confirmed using videotaped observations.

The water ergometer test was undertaken on the same day using a tubular rubber band, stretching from the edge of the pool tied to the subject's flotation belt. Water running ergometry began with the metronome starting at 60 cycles/minutes for five minutes, with each cycle consisting of one complete cadence cycle (two steps). The ergometry speed was then increased by 10 cycles/minute each two minutes until the participant reached physiological or volitional fatigue to end the test. Each participant was instructed to "go all out" during the final minute. HR was monitored continuously at one second intervals using the Polar 610i Heart Rate Monitor. At the same time, ratings of perceived exertion (RPE) were measured each two minutes. The 11-point Modified Borg Scale (0–10 scale) was used to measure RPE at 2 min intervals (Pfeiffer, Pivarnik, Womack, Reeves, & Malina, 2002).

All data were collected by the same investigators. During both tests at the end of each two-minute stage, without interrupting the incremental process of the test, blood was obtained by a puncture of the ear lobe. The heart rate was monitored with the Polar heart rate monitor on the chest and transmitted to a receiver on the wrist. The running form of the subjects was videotaped and monitored simultaneously by one of the experimenters throughout the testing. The correct running technique was monitored during the whole test to ensure that the only incremental variable was cadence and that the running coordination did not vary.

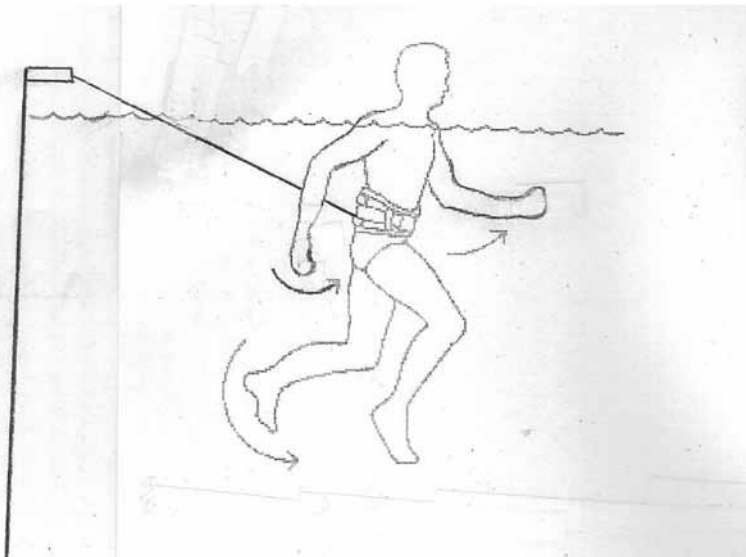


Figure 1 — Symbolized drawing of deep-water running.

Statistical Analysis

Statistical calculations were performed using SPSS 12.0.1. The arithmetic means \pm *SEs* were calculated for each parameter and group. The means of all parameters were then compared using repeated measures paired *t* tests. For all statistical measures, significance was established at the 0.05 level of probability.

Results

Table 2 shows the results (means \pm *SD*) and one-tailed repeated measures *t* tests comparing the measured variables. The average maximum heart rate was 14.9 bpm lower during the water test than during the land test ($p = .001$, 95% confidence interval, 7.74–22.05). The three-minute recovery heart rate was 16.4 bpm lower after the water exercise than the land running test ($p = .012$, 95% confidence interval, 4.57–28.23). No significant differences were found in the resting heart rate, maximum blood lactate (maxBLC) level, or the rating of perceived exertion (RPE).

The equal maxBLC of HR in the TM process and in DWR suggest the similarity increasing effort. Some authors compared aerobic values less than 60% of

Table 2a Results

	Means	SD
REST-HR TM Vs DWR	80,700	7,334
	77,100	11,149
MAX-HR TM Vs DWR	190,300	5,334
	175,400	9,323
3MIN REC-HR TM Vs DWR	129,200	13,087
	112,800	6,460
MAX-lact TM Vs DWR	10,944	1,414
	10,267	1,885

Table 2b Results

Variables	Means	SD	CI 95%		Sig. (bilateral)
			Inf.	Sup.	
REST-HR TM Vs DWR	3,6000	15,450	-7,452	14,652	,480
MAX-HR TM Vs DWR	14,900	10,005	7,742	22,057	,001
3MIN REC-HR TM Vs DWR	16,400	16,534	4,572	28,227	,012
MAX-lact TM Vs DWR	,677	2,028	-,773	2,127	,319

the highest theoretical value of HR during walking on TM and in DRW and there were no differences in the results (Gleim, & Nicholas, 1989; Whitley, & Schoene, 1987); however, according to our results, as other authors (Butts, Tucker, & Christine, 1991; Eyestone, Fellingham, George, & Fisher, 1993) above of 140 HR the differences among the values of HR are higher in the physical exercise developed on TM and in DRW. The results of this study are in accordance with values given by other authors who are among 10% (Butts, Tucker, & Christine, 1991), 14% (Coyle, Hemmert, & Coogan, 1984) and 16% (Eyestone, Fellingham, George, & Fisher, 1993).

Discussion

Maximal BLC values were greater than 8mmol/L in both tests without significant differences, which suggests that the test intensity was maximal and of a similar intensity in both tests (Wilmore & Costill, 2004). There were not any significant differences in the HR values on TM and HR in DWR before the tests began. The results show significant differences in the maximal HR and in HR3min, for both tests maximal effort. This could mean that there is a cardiovascular response in this population in DWR to a maximal exertion of similar characteristics and therefore this test could be an option to reproduce the assessment of maxHR.

This test could be useful for the control of the maximum heart rate and the three-minute recovery heart rate. The maximum heart rate was 7.83% lower in water than for the standard laboratory ergometer test performed on land. Others have proposed values ranging from 10% (Butts et al., 1991), to 14% (Coyle et al., 1984), to 16% (Eyestone et al., 1993; Takeshima et al., 1997) for various populations of international level sportspersons. Although some authors found no differences in aerobic heart rate levels less than 60% of the theoretical maximum heart rate values between walking on land and in water (Gleim & Nicholas, 1989; McMurray, Fieselman, & Avery, 1988; Whitley & Schoene, 1987), this study like some others (Butts et al. 1991; Eyestone et al. 1993) found that above 140 bpm the differences in heart rate are greater between water-based and land-based exercises.

Conclusions

In the current study, the results demonstrated that the cardiovascular response to the exercise taken part by the water immersion and, although deep water running offers many therapeutic and training possibilities, is necessary to design a specific test like exposed in material and method or its defect to realize an estimation from the tests in dry that habitually they present these sportsmen.

The specific test of the DRW is shown to be a toll to prescribe training exercises at different HR intensities and the planning of compensatory training in injuries recovery period on the basis of these data. In the case that the specific test in DRW was not possible to apply in subjects belonging to a population with similar characteristics.

Future studies need to carry out analyses with larger samples sizes because it is difficult to obtain a proper size of them in this population of elite sportsmen.

These results could be applied to sportsmen of an international level where we find great demand of this kind of intervention of physiotherapy in injuries recovery.

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