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Workload demand in police officers during mountain bike patrols

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To the authors' knowledge this is the first paper that has used the training impulse (TRIMP) 'methodology' to calculate workload demand. It is believed that this is a promising method to calculate workload in a range of professions in order to understand the relationship between work demands and aerobic fitness. The aim of this study was to assess workload demand in police officers from the Utrecht police department in the Netherlands, during patrol by mountain bike. Maximum oxygen intake, maximum heart rate (HR_{max}), ventilatory threshold (VT)1 and VT2 were determined with a maximal exercise test on a bicycle ergometer. Heart rates were registered throughout three shifts in 20 subjects using a heart rate monitor. Exercise intensity was divided into three phases: phase I (between 40% of HR_{max} and VT1); phase II (between VT and the respiratory compensation point (RCP)); and phase III ($> RCP$). The total TRIMP score was obtained by summing the results of the three phases. Average daily workload demands of 355 TRIMPs per day and 1777 TRIMPs per week were measured. Workload demand approached and in some cases exceeded the upper limit of 2000 TRIMPs per week threshold level for physiological stress demands in professional male cyclists.

Keywords: physical workload; TRIMP; VO_{2max} ; HR_{max}

Introduction

Despite mechanical automation, high intensive muscular and cardiovascular efforts are still common among various professions (Shimaoka *et al.* 1998, Aminoff *et al.* 1999, Bos *et al.* 2004a, Stapelfeldt *et al.* 2004). Sustained high intensity work is associated with exhaustion and physiological stress and may increase the likelihood for work-related accidents and mistakes, due to the fact that exhaustion reduces a worker's accuracy (Aminoff *et al.* 1998, Voss *et al.* 2001, Bos *et al.* 2004b, Bugajska *et al.* 2005, Kawada and Ooya 2005, Lund *et al.* 2006). Some studies describe a relationship between workload demand and sick leave and drop-out levels (Voss *et al.* 2001, Bugajska *et al.* 2005, Kawada and Ooya 2005). Restrictions concerning maximum acceptable work time for physiological high intensity work have been reported in the literature (Jørgensen 1985, Padilla *et al.* 2000, Wu and Wang 2001, 2002, Wu *et al.* 2005, Foster *et al.* 2005). Acceptable limits for physical work of 8 h duration based on physiological criteria is suggested to be 50% of maximal oxygen uptake (VO_{2max}) in trained subjects and 35% of VO_{2max} in untrained subjects (Jørgensen 1985).

Heart rate (HR) and oxygen uptake (VO_2) are important indicators for exhaustion and physiological stress (Aminoff *et al.* 1998, Foster *et al.* 2005, Lund *et al.* 2006). Both measures are commonly used to determine workload demand in occupational or sport settings (Bos *et al.* 2004b, Lund *et al.* 2006). A physiological workload requires a certain amount of oxygen per min; when the workload increases, VO_2 will also increase. VO_2 is thus directly related to the energy expenditure of work and indicates the intensity of the workload. A person with a large VO_{2max} is therefore able to withstand a higher workload than a person with a lower VO_{2max} . HR can be used as a surrogate index for VO_2 since it has a linear relationship with VO_2 during moderate and heavy exercise (Åstrand and Rodahl 1986). Due to the large inter-subject variability of HR and VO_2 , workload is often described in terms of a percentage of maximum HR ($\%HR_{max}$) or as a percentage of VO_{2max} (Åstrand and Rodahl 1986, Swain and Leutholtz 1997, Swain *et al.* 1998, Shimaoka *et al.* 1998, Aminoff *et al.* 1999, Bos *et al.* 2004b, Stapelfeldt *et al.* 2004). To assess workload demand using $\%HR_{max}$ or $\%VO_{2max}$

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alone is not sufficient, however, as workload is a function of both intensity and duration of physical work.

As a method for integrating both duration and intensity of physical work, Banister *et al.* (1975) developed the concept of training impulse (TRIMP) using $\%HR_{max}$ as a variable. The integration of both $\%HR_{max}$ and duration to compute TRIMP units provides a reliable marker to calculate workload demand (Lucia *et al.* 2003, Esteve-Lanao *et al.* 2005, Foster *et al.* 2005). Foster *et al.* (2001, 2005) further developed this theory and suggested developing different TRIMP units according to HR zones. For computing the total workload demand for 1 d, all TRIMPs from the different HR zones are summed up. This concept is frequently used in recent studies concerning workload demands in professional sportsmen (Banister *et al.* 1975, Lucia *et al.* 2003, Esteve-Lanao *et al.* 2005). Based on data from professional road cyclists, Foster *et al.* (2005) proposed that 2000 TRIMP units per week is the upper limit for high intensity muscular and cardiovascular effort, which can be sustained for an extended time period of maximally 3 weeks. By staying below this limit, professional road cyclists can prevent exhaustion and physiological stress.

One of the fastest growing trends in law enforcement and emergency medical response today in North America and Europe is the utilisation of mountain bicycles. Quiet, cost efficient and amazingly effective, mountain bikes are able to bridge the gap between automobiles and foot patrols (International Police Mountain Bike Association 2008). However, police cyclists may face a high workload. Police officers from the police department of the city of Utrecht, the Netherlands, who patrol by mountain bike (bikers) are exposed to an 8 h working day with an average cycling distance of 40 to 50 km. Their workload demand is characterised by mountain bike patrols and intermittent high intensity sprints, 5 d per week in irregular shifts. The majority of the time they are riding their bike. Only when they have to do law enforcement duties (e.g. arresting, writing fines, administrative tasks, etc.) are they off the bike. Usually, the officers have a 30 min break during the work day.

The department has to cope with approximately 15–20% of these police officers resigning from the team per year and a high level of sick leave. This is possibly due to the relationship between high workload demand, sick leave and drop-out levels (Voss *et al.* 2001, Bugajska *et al.* 2005, Kawada and Ooya 2005). It is interesting as well as necessary to determine workload demand in this particular group of police officers. Therefore, the aim of this study was to assess workload demand in police officers from the Utrecht police

department in the Netherlands during patrols by mountain bike.

Material and methods

Design

All subjects performed a maximal bicycle ergospirometry test to determine HR_{max} and VO_{2max} , ventilatory threshold (VT1) and respiratory compensation point (VT2). Throughout three 8-h shifts, on the job HR registration took place in 20 police officers from the Utrecht police department during patrols by mountain bike. Using the HR_{max} and the registered on the job HRs, TRIMP units were computed, to assess the workload demand (see Procedure).

Subjects

By convenience sampling, 20 healthy bikers from the Utrecht police department were recruited from a total population of 98 bikers. Inclusion criteria included active male and female police officers from the Utrecht police department with a minimum of three mountain bike patrol shifts per week. All bikers were invited via a recruitment letter. The 20 bikers first to respond were included. The participants were informed about the study, first by the recruitment letter, second by their training instructor and third at the first meeting with the researchers. All participants received a written explanation of the background of the study, its objectives and their involvement. All subjects signed an informed consent prior to enrolment into the study. The study was conducted in accordance with the ethical principles that have their origin in the Declaration of Helsinki and are consistent with good clinical practice.

Procedure

All participants performed a maximum ergospirometry test on a cycle ergometer at the exercise laboratory from the University of Applied Sciences Utrecht to determine VO_{2max} , HR at the ventilatory threshold (VT1), respiratory compensation point (VT2) and HR_{max} .

First, the cycle ergometer was adjusted to the subject's physique. Before the ergospirometry test was performed, subjects performed a 3-min warm-up procedure. Thereafter, the subjects performed the maximum exercise test, using an increasing resistance of 20 Watts per min, starting at zero Watts. The pedalling frequency was maintained at 60 revolutions per min. The computer continuously measured VO_2 and HR. VT1 was determined using the criteria of an

increase in both VE/VO_2 and $PETCO_2$ with no increase in VE/VCO_2 , whereas the VT2 was determined using the criteria of an increase in both VE/VO_2 and VE/VCO_2 and a decrease in $PETCO_2$ (Lucia *et al.* 2000). VE indicates ventilation, $PETCO_2$ indicates end-tidal pressure of O_2 , VCO_2 indicates CO_2 output, and $PETCO_2$ indicates end-tidal pressure of CO_2 . In general, the test lasted between 10 to 17 min.

Prior to the ergospirometry test, BMI was calculated (kg/m^2), from body mass and height.

At the first appointment of the study, all subjects received a Polar Vantage heart rate monitor with breast band and wrist watch (Polar Nederland BV, Almere, The Netherlands). All subjects were verbally instructed as to how to use the watch and chest band, they also received written instructions. The participants were requested to put on the watch and chest band at the start of each shift and to take them off at the end of the shift, for a total of three shifts. During the on the job measurement, the Polar Breast band was put around the chest at the level of the heart. The Polar Vantage heart rate monitor automatically registered HR data every 15 s during a shift. The data from each shift were automatically stored in the memory of the monitor. The saved files were transferred to a computer using a sonic link or infrared gate and then imported into a Microsoft Excel© data file (Microsoft Corporation, Richmond, WA, USA). Absolute HR data were transformed into TRIMPs according to Lucia *et al.* (1999). According to this approach, the

HR-defined zones associated with VT1 and VT2 were calculated. Subsequently, the TRIMP model was categorised based on HR falling into one of three of the following categories: zone 1 (light intensity, below the VT1 but higher than 40% of HR_{max}); zone 2 (moderate intensity, between the VT1 and VT2); and zone 3 (high intensity, above VT2; see Figure 1) (Lucia *et al.* 1999). The score for each zone is computed by multiplying the accumulated duration in this zone by a multiplier for this particular zone (e.g. 1 min in zone 1 is given a score of 1 TRIMP, 1 min in zone 2 is given a score of 2 TRIMP and 1 min in zone 3 is given a score of 3 TRIMP). The total TRIMP score is then obtained by adding the results of the three zones. Moreover, a weekly estimate was calculated as the average daily TRIMP score \times 5 d (Esteve-Lanao *et al.* 2005, Foster *et al.* 2005).

Statistical analysis

To calculate HR zones and TRIMP units Microsoft Excel© was used. Descriptive analysis of the data was performed by using SPSS v12.0 (SPSS Inc., Chicago, IL, USA). Normal distribution of the data was tested using the Shapiro–Wilks test.

Results

The group consisted of 16 male and four female bikers, with a mean age of 32 ± 8 years and 25 ± 5 years

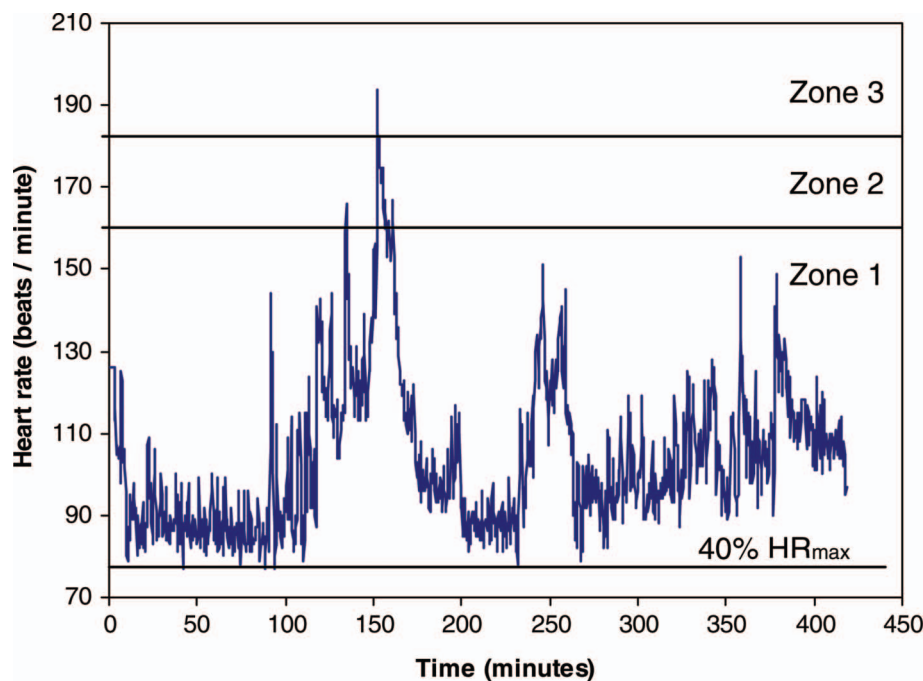


Figure 1. Typical example of a heart rate trace of a police officer during mountain bike patrol. HR_{max} = maximum heart rate.

Table 1. Characteristics of the subjects (n = 20).

Parameter	Male (n = 16)	Female (n = 4)
Age (years) \pm SD (range)	32 \pm 8 (21–45)	25 \pm 5 (22–32)
Weight (kg) \pm SD (range)	85.1 \pm 6.3 (74–95)	59.5 \pm 2.3 (57.0–61.5)
Height (cm) \pm SD (range)	183.5 \pm 7.9 (169–198)	168 \pm 2.0 (166.0–170.0)
BMI (kg/m ²) \pm SD (range)	25.3 \pm 2.0 (22.7–29.4)	21.1 \pm 0.3 (20.7–21.3)
HR _{max} (beats per min) \pm SD (range)	179 \pm 8 (167–191)	178 \pm 5 (173–184)
VO _{2max} (ml/min per kg) \pm SD (range)	44.6 \pm 6.0 (30.2–50.8)	35.1 \pm 8.2 (25.8–40.9)

HR_{max} = maximum heart rate; VO_{2max} = maximum oxygen uptake.

Table 2. Time and intensity.

	Total time (min) \pm SD (range)	Zone 1 Low intensity	Zone 2 moderate intensity	Zone 3 High intensity
Male	335 \pm 91 (141–486)	315 (93%)	15 (5.7%)	4 (1.3%)
Female	332 \pm 25 (305–354)	320 (96%)	11 (3.5%)	2 (0.5%)
Total (% of time)	334 \pm 84 (141–486)	316 (93.5%)	15 (5.3)	4 (1.2%)

Zone 1 = exercise intensity in heart rate zone between below VT1 and maximum heart rate > 40%; zone 2 = exercise intensity in heart rate zone between VT1 and VT2; zone 3 = exercise intensity above VT2.

respectively and BMI was 25.3 \pm 2.0 kg/m² and 21.1 \pm 0.3 kg/m² respectively. The participating male bikers attained mean VO_{2max} values of 44.6 \pm 6.0 ml/kg per min vs. 35.1 \pm 8.2 ml/kg per min for the female bikers on the incremental laboratory test, HR_{max} was 179 \pm 8 bpm vs. 178 \pm 5 bpm respectively. Characteristics of the participants are shown in Table 1.

The male bikers had an average exercise time of 339.8 \pm 94.1 min (range: 100.0–499.8) per day, of which 334 min (\pm 84, range: 141–486) were with an activity > HR_{max} 40%.

A total of 94% of the time was spent in low intensity zone (zone 1), 5% in the moderate intensity zone (zone 2) and 1% in the high intensity zone (zone 3) (see Table 2).

The distribution of TRIMP units between male and female bikers is presented in Table 3. The average amount of TRIMP units for one working day was 357 \pm 80 (range: 153–486). The estimated weekly workload for a biker equated to 1783 \pm 402, range (764–2429) TRIMP units/week.

In Table 4, the comparison of the TRIMP units produced by the bikers with TRIMP units of other studies is presented and shows that the workload demand of bikers is comparable with professional cyclists during competition. Interpolation and extrapolation of the TRIMP data in these papers was used to measure exercise time in the present study (339.8 min).

Discussion

The present study aimed at assessing workload demand in police officers from the Utrecht police

Table 3. Training impulse (TRIMP) units daily and weekly.

	TRIMP (day) \pm SD (range)	TRIMP (week) \pm SD (range)
Male	359 \pm 87 (153–486)	1793 \pm 435 (765–2429)
Female	346 \pm 36 (305–368)	1732 \pm 181 (1523–1823)
Total	357 \pm 80 (153–486)	1783 \pm 402 (765–2429)

department. The present data demonstrate that the average weekly workload measured in this study was 1783 TRIMP in police officers, during patrols by mountain bike. TRIMP units measured in these police officers from the Utrecht police department approached, or in five cases exceeded, the threshold of 2000 TRIMP units per week. Foster *et al.* (2005) described a threshold level for physiological stress demands in professional male cyclists at 2000 TRIMP units per week. Workload demands above this threshold might lead to exhaustion and physiological stress. The threshold level stipulated by Foster *et al.* (2005) was based on male professional cyclists with an average VO_{2max} of 75.9 \pm 6.5 ml/kg per min. In the present study, male police officers from the Utrecht police department had a VO_{2max} of only 44.6 \pm 6.0 ml/kg per min. As VO₂ has a linear relationship with HR, a decrease in VO_{2max} will lead to an increased amount of TRIMP units and therefore increased workload demand.

Workload demands in police officers during mountain bike patrols have not previously been investigated. Few papers (Padilla *et al.* 2000, 2001, Lucia *et al.* 2003), concerning male professional road cyclists, have reported workload demand using

Table 4. Training impulse (TRIMP) units and comparison with literature.

	Current study	Lucia <i>et al.</i> 2003	Padilla <i>et al.</i> 2001	Padilla <i>et al.</i> 2000
TRIMP units mean (\pm SD)	357 \pm 80	395 \pm 16	335 \pm 15	215 \pm 38
Time (min)	339.8	308	254	355
TRIMP units for a working day of 339.8 min	357 \pm 80	435*	447*	206*
				146 \pm 6
				75.3
				658*

*TRIMP units intra- or extrapolated to 334 min to compare with results in this study.

TRIMP units. Padilla *et al.* (2000) measured workload demand during time trials in professional road cyclists. The maximum amount of TRIMP units was calculated during the team time trial. The team time trial lasted 73.3 min, in this period an average effort of 146 TRIMP units was expended. The same authors measured exercise intensity during mass-start races in professional road cycling (Padilla *et al.* 2001). The participants exercised for an average duration of 355 min on a high mountain stage with 215 TRIMP units calculated. To compare workload between the Tour de France and Vuelta a Espana, Lucia *et al.* (2003) also used TRIMP units. The total workload did not significantly differ between the two races (395 TRIMP units per day in the tour vs. 335 TRIMP units in the Vuelta), despite a longer total exercise time in the Tour, 308 min per day vs. 254 min. It should be taken into consideration that TRIMP units are calculated by time and intensity. In a rather short period of time a cyclist can produce a large amount of intensity and thus a high amount of TRIMP units. Due to the method of extrapolation, the total number of TRIMP units will obviously be higher; for example, in Padilla *et al.* (2000). The intra- and extrapolation from the data in the other papers is more reliable because exercise time is approximately equal to the present study (Padilla *et al.* 2001, Lucia *et al.* 2003). This means that workload demand in professional cyclists is comparable to workload demand measured in police officers during patrols by mountain bike in Utrecht. Professional cyclists have races with a maximum duration of 21 d (Tour de France). Bikers have to cope with this workload demand during the whole year.

The current study has some possible limitations. First, HR was used to calculate TRIMP units in order to determine workload demand. HR is a variable that is influenced by multiple contextual factors such as age, level of fitness, anxiety level and mental stress (Louhevaara *et al.* 1988, Ceesay *et al.* 1989, Strath *et al.* 2000, Hunn *et al.* 2002, Garet *et al.* 2005). Police officers are prone to situations of high mental stress during patrols (Sorensen *et al.* 2000). During the testing period, the HR of the bikers may have been

increased by mental stress, which might have led to a higher amount of TRIMP units. However, Astrand and Rodahl (1986) described that contextual factors, such as mental stress, do not affect the HR if it exceeds 120 bpm. To exclude the effect of mental stress as a confounder for workload demand, future research could be directed to the difference in workload between police officers in cars and police officers during patrols by mountain bike. Moreover, mobile power measurement devices can be used to measure workload demand during cycling as has been done in professional cyclists (Vogt *et al.* 2007). Moreover, leisure time physical activities and the transportation to and from work of the officers must be monitored as well, since they might contribute significantly to the physical demand of the work week. Second, some bikers ($n = 2$) had two very short shifts of 231 min and 253 min ($-2.7 \times$ SD), respectively and therefore a lower amount of TRIMP units. This might be caused by a failure in the HR monitor, because shifts with such a short duration are uncommon. These outliers caused a left skewed normal TRIMP unit distribution curve. By excluding these shifts, a normal curve occurs that leads to a higher average amount of TRIMP units, namely, 376 per day and 1880 per week.

A threshold level of 2000 TRIMP units per week was described by Foster *et al.* (2005). The present study measured TRIMP units that exceeded this threshold level. This study did not include drop-out and sick leave data and therefore could not investigate the relationship of high TRIMP units with drop-out and sick leave data. Further research is recommended. It also seems advisable to start workload-specific training prior to being a police mountain biker, because there is evidence that training might be associated with improved performance during high intensity endurance events (Esteve-Lanao *et al.* 2005). Adequate training will lead to an increase in VO_{2max} , reducing the workload demand due to the linear relationship between VO_{2max} and HR. Moreover, the workload demand could be reduced by using appropriate tyres, sufficient tyre pressure and ergonomic bike positioning to diminish rolling and air resistance.

Conclusion

In conclusion, the workload demand of police officers during mountain bike patrols is very high when compared to the workload of professional road cyclists and it exceeds commonly used threshold levels. This high workload demand might be a possible explanation for the high sick leave level and number of bikers resigning from the team. To reduce drop-out and sick leave levels, further research aimed at increasing exercise capacity and decreasing workload demand in police officers from the Utrecht police department during patrols by mountain bike is suggested.

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