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Energy Expenditure in Physical Education Teachers using the Relationship between Heart Rate and Oxygen Consumption

Junjie Chen [a, *], Longfei Yan [a]

[a] Department of Energy and Power Engineering, School of Mechanical and Power Engineering, Henan Polytechnic University, Jiaozuo, Henan, China

Abstract

The energy expenditure in physical education teachers is studied. Sixty physical education teachers have their individualized linear function between oxygen consumption and heart rate measured by laboratory testing. The heart rate is recorded on two different days at work to estimate the energy expenditure, correlated with a diary of daily tasks. The average absolute energy expenditure is low when expressed in relative values and low-to-moderate when expressed in absolute values. However, these physical education teachers often reach very high intensities. The physical education teaching requires a light-to-moderate energy expenditure with more intense periods of physical activity. The variety of tasks performed can significantly affect energy expenditure.

Keywords: energy expenditure, oxygen consumption, heart rate, physical education, physical activity, physical educators.

1. Introduction

Physical educators are a special category of teachers. The physical work load in physical education teachers is very heavy (Sandmark, 2000). Physical education teachers expend high energy levels with some heart rate episodes of 150 beats per minute (bpm), making them as heavy as for lumberjacks, farmers, and construction workers (Sandmark *et al.*, 2000). Such heavy workloads have also been associated with a high rate of musculoskeletal dysfunction and injuries (Lemoyne *et al.*, 2007). Physical education teachers experience several occupational constraints and a high risk of physical injury associated with a high attrition rate (Engström *et al.*, 1999). Indeed, in a qualitative survey of physical education teachers, few perceived themselves as being able to actively continue their profession until retirement age (Bizet *et al.*, 2010).

In previous studies, the energy expenditure among physical education teachers has not been quantitatively assessed. Sandmark *et al.* (1999) analyzed their work tasks by direct observation. High physical load may be caused by prolonged standing, stress and repetitive or sudden movements, by equipment handling, by supporting the load of student weights under certain conditions (Sandmark *et al.*, 1999). Not only do they have to lift students in parades for gymnastics or psychomotor learning, often in awkward and difficult positions, but they are also exposed to additional horizontal shear forces. Ultrafast, dynamic forces can inflict large and sudden mechanical loading with increased risk of musculoskeletal injuries or fractures. Heart rate (HR)

* Corresponding author
E-mail addresses: jgnjie@163.com (J. Chen)

was recorded per daily work duration and was on average above 100 beats per minutes for 42 % of the work period in women, and 25 % in men (Sandmark *et al.*, 1999). Activities which generated the highest heart rates were warm-ups, aerobic exercises, dance and circuit training. In these activities, teachers usually participated and helped students through demonstrations. Participation in warm-ups, aerobic exercise and support of students in gym class generated peak heart rates of 150 beats per minutes or more (Sandmark *et al.*, 1999). Trudeau *et al.* (2015) quantified work energy expenditure in physical educators, and found that physical educators should be prepared to perform tasks with different levels of energy expenditure.

However, the relative workload that these physical education teachers must face is still unclear in the literature. The heart rate has not been converted into energy expenditure values. Furthermore, the average percentages of maximum metabolic capacity that physical education teachers must endure every workday have not been studied. The objective of this study is to quantify energy expenditure in physical education teachers in their work environment. Of particular interest in the present work is to examine the effect of various conditions, such as teaching levels, types of tasks performed, gender, age, and years of experience, on the energy expenditure.

2. Methods

2.1. Participants

In this study, sixty (60) physical education teachers from the Jiaozuo city, involved at different levels of education, volunteered to participate. A special feature in the Jiaozuo city is that across all school levels, i.e., from primary to college, physical education is taught by specialists. The sample includes 20 teachers from primary schools (10 males and 10 females), 20 from secondary schools (10 males and 10 females), and 20 from colleges (10 males and 10 females). Table 1 shows the number of participants at each school level according to years of experience. Each eligible participant visits once in the laboratory, and data are collected twice in the field. Informed signed consent is obtained in the laboratory session, and health status is profiled according to procedures for the risk stratification. Additionally, anthropometric and fitness variables are measured. Oxygen consumption/heart rate regression equation is developed during progressively maximal treadmill testing. During the laboratory visit, participants experience two workdays for data collection in the field. During these workdays, each of them wear a heart rate monitor with built-in memory and an accelerometer to quantify movement counts.

Table 1. Number of participants at each school level according to years of experience

Teaching level	Years of experience
Primary school	10 Males (6 LE, 2 AE and 2 HE) 10 Females (4 LE, 3 AE and 3 HE)
High school	10 Males (4 LE, 2 AE and 4 HE) 10 Females (5 LE, 3 AE and 2 HE)
College	10 Males (3 LE, 3 AE and 4 HE) 10 Females (4 LE, 4 AE and 2 HE)
Total	26 LE, 17 AE, and 17 HE

LE: less experienced (five years or less), AE: average experience (six to fifteenth years), and HE: highly experienced (sixteenth years or more).

2.2. Tests and measurements

At the beginning of the laboratory session, the blood pressure (BP) is monitored by sphygmomanometer (Tycos Healthometer, Mansfield, Mass., USA) on two occasions separated by ten minutes. Anthropometric measurements were undertaken. The weight of each participant is measured with a beam balance (Detectomedic, Detecto Scales, Inc., Brooklyn, NY, USA). Participant height is measured by stadiometer (Healthometer, Bridgeview, IL, USA), and the waist circumference (WC) is measured by tape. Finally, the skinfold thickness is measured on the right side of the body with an adipometer (John Bull British Indicators, UK).

2.3. Muscle capacities and energy expenditure estimation

The back muscle (modified Sorensen test) and abdominal muscle (sit and reach) endurance, leg power (vertical jump), elbow extensor/shoulder flexor endurance, hip flexibility, and handgrip strength are quantified. The energy expenditure is computed on the basis of interpolation of regression built with the relationship between heart rate and oxygen consumption (VO_2), by maximal incremental laboratory testing. To determine this relationship, a regression equation specific to each subject is computed, and then the heart rate is measured at the worksite. The corresponding predicted value of oxygen consumption is computed by interpolation.

2.4. Oxygen consumption and heart rate

The heart rate monitoring has emerged as a kind of very effective method to estimate the energy expenditure based on the well-established relationship between heart rate, oxygen consumption and energy consumption (Achten and Jeukendrup, 2003, Swain, 2000, Wicks *et al.*, 2011). The heart rate monitoring has also been used to evaluate the level of physical activity (Bouchard and Trudeau, 2008, Lee *et al.*, 2009, Rennie *et al.*, 2001, Takken *et al.*, 2010, Tanhoffer *et al.*, 2012, Wicks *et al.*, 2011). In large population-based studies, the heart rate monitoring is one of the most efficient and economical means of estimating free-living energy expenditure. It also provides useful insights into the intensity of the physical activity being undertaken over the measurement period (Keytel *et al.*, 2005). However, the heart rate monitoring duration is limited by the data storage capacity of the device used (Achten and Jeukendrup, 2003). The validation of heart rate for measuring the energy expenditure has been performed mostly via the oxygen consumption testing during high intensity exercise (Bouchard and Trudeau, 2008, Ceesay *et al.*, 1989, Keytel *et al.*, 2005, Wicks *et al.*, 2011).

In the laboratory, participants are tested by progressive maximal modified Bruce protocol for treadmill exercise with three-minute increments to achieve a steady state. Before the stress tests, the relationship between heart rate and oxygen consumption is measured when the subjects are seated. Incremental testing is continued until maximal oxygen consumption to ascertain the maximum aerobic capacity of each participant. Expired gases are assessed by the MetaCheck metabolic rate analysis system to measure the oxygen consumption. Prior to use, all these devices have been calibrated. Criteria for determining the maximum are as follows: the respiratory exchange ratio higher than 1.10; participant inability to continue the current level or to progress to another workload; achievement of theoretical maximum heart rate, i.e., 220 – age; and plateau identification (±150 ml) of oxygen consumption gain. At least three of these four mandatory criteria must be met with achievement of the required respiratory quotient.

During the treadmill stress test, the heart rate is recorded by the transmission belt coupled to a receiver connected to a data acquisition system. The same monitor records the heart rate during work. Research assistants go to all sites to install wrist heart rate monitors and hip accelerometers and to deliver task diaries for completion. At the end of the day, research assistants return to all sites to collect the equipment and help physical education teachers to complete their logbooks. The data of heart rate and accelerometry counts are averaged over each one-minute period for further computation. Energy expenditure values during selected work phases are estimated by interpolation of oxygen consumption/heart rate linear function specific to each individual.

2.5. Accelerometry and diary

Each participant wears a belt accelerometer (Actigraph, MTI Health Services, Pensacola, FL, USA) during work to estimate amounts of movements during a given time period of the day. It serves to verify movement periods occurring during work and to corroborate diary entries. In the logbook, participants describe tasks performed during the day in bouts of ten minutes. After the analysis of all participant logs, four categories of activities are identified according to their energy expenditures. First category: office work (telephone, paperwork, meetings, marking of assignments, displacements in school or between schools, and course preparation). Second category: supervision and monitoring (observation, monitoring at recess, student assessment, surveillance of facilities, student management and courses without demonstrations). Third category: mixed participation (partly-active refereeing, demonstrations followed by educational supervision, assisting students in carrying out activities). Fourth category: active participation (participation while teaching and active refereeing involving running and game's involvement at the same pace as the pupils).

In none of the data collection periods, the ambient temperature is higher than 25.6 °C, i.e., a threshold value (Trudeau *et al.*, 2015). In fact, the two main data collection periods in spring are cooler than average. Data are expressed as means ± standard deviations. The analysis of variance (ANOVA) with least significant difference (LSD) test are used to evaluate the differences in the energy expenditure values. The correlations between the different energy expenditure methods are evaluated by Pearson correlation coefficients. Linear regression analysis with a stepwise method is used to assess whether the differences between the tested methods are affected by teaching levels, types of tasks performed, gender, age, and years of experience. STATISTICA software (StatSoft Inc., Tulsa, OK, USA) is used to perform all statistical analyses. A p-value less than 0.05 is considered statistically significant.

3. Results

3.1. Participant characteristics

Table 2. Participant characteristics

	Males	**Females**	**Males + females**
Weight (kg)	70.48 ± 9.36	60.26 ± 9.07	65.37 ± 18.43
Height (cm)	170.77 ± 6.04	160.42 ± 4.92	165.60 ± 10.96
Body mass index (kg/m^2)	24.07 ± 2.58 Normal	23.48 ± 3.16 Normal	23.78 ± 2.87
Waist circumference (cm)	77.48 ± 7.78 Low risk	64.66 ± 5.58 Low risk	71.07 ± 13.36
Age (years)	38.92 ± 8.67	32.48 ± 6.77	35.70 ± 7.72
Years of experience (years)	10.88 ± 8.27	8.96 ± 3.96	9.92 ± 6.12
Sum of 5 skinfolds (mm)	49.46 ± 18.68	59.38 ± 22.96	54.42 ± 20.82
% Fat	18.48 ± 4.57 Good	20.22 ± 5.46 Good	19.35 ± 5.02
Diastolic pressure (mmHg)	75.2 ± 7.7 Optimal	74.2 ± 9.2 Optimal	74.7 ± 8.5
Systolic pressure (mmHg)	116.7 ± 5.6 Optimal	115.7 ± 8.8 Optimal	116.2 ± 7.2
VO_2 max (ml·kg^{-1}·min^{-1})	50.68 ± 7.86 85th percentile Excellent	46.56 ± 4.48 94th percentile Excellent	48.62 ± 6.17
Hand grip strength (total left + right in kg)	90.0 ± 22.7 Acceptable	82.0 ± 20.8 Excellent	86.0 ± 21.8
Push-ups (number/min)	22.6 ± 8.0 Very good	26.8 ± 8.4 Excellent	24.7 ± 8.2
Trunk flexion (cm)	28.6 ± 8.0 Good	32.6 ± 7.6 Good	30.6 ± 7.8
Partial curl-ups (number)	23.6 ± 5.0 Very good	23.8 ± 4.6 Very good	23.7 ± 4.8
Leg power (watts)	4486.7 ± 848.6 Good	3786.7 ± 748.7 Excellent	4136.7 ± 798.7
Back extension (s)	148.7 ± 28.6 Excellent	127.6 ± 46.7 Very good	138.2 ± 37.7

Table 2 shows the participant characteristics. Depending on the fitness variable measured, participants have a fitness rating of "good-to-excellent" for their age group in both men and women. The aerobic fitness of both male and female physical education teachers is categorized as excellent. Cardiovascular risk variables, such as blood pressure, body mass index (BMI), and waist circumference (WC), are considered optimal in male and female teachers. There is no effect of age on the maximal oxygen consumption, as indicated by the zero correlation between age and maximal oxygen consumption. Height, weight, body mass index, waist circumference, and back extension (modified Sorensen) are significantly greater in males than in females. Males have significantly more years of experience than female teachers.

3.2. Energy expenditure by gender

Table 3. Energy expenditure according to gender and estimated intensity of workday

	Intensity of workday	Males	Females	Males + females
Average duration of workdays (min)	Less intense	332.8 ± 79.6	335.6 ± 56.0	334.2 ± 67.8
	More intense	366.6 ± 73.8	389.7 ± 48.7	378.2 ± 61.3
% of VO_2 max (energy expenditure)	Less intense	16.6 ± 9.6%	16.8 ± 6.8%	16.7 ± 8.2%
	More intense	22.6 ± 11.6%	24.8 ± 4.8%	23.7 ± 8.2%
kcal·min^{-1} (energy expenditure)	Less intense	2.98 ± 1.88	2.45 ± 1.44	2.72 ± 1.66
	More intense	4.08 ± 2.26	3.26 ± 0.88	3.67 ± 1.57
% of time at ≥100 bpm	Less intense	14.6 ± 15.6%	14.8 ± 9.7%	14.7 ± 12.7%
	More intense	19.2 ± 20.8%	16.7 ± 19.7%	18.0 ± 20.3%
% of maximal heart rate during periods at >100 bpm	Less intense	60.8 ± 6.6%	63.8 ± 8.6%	62.6 ± 7.6%
	More intense	62.7 ± 6.7%	66.8 ± 2.7%	64.8 ± 4.7%
kcal·min^{-1} during periods at >100 bpm	Less intense	13.0 ± 2.8	9.0 ± 2.8	11.0 ± 2.8
	More intense	13.2 ± 2.6	8.8 ± 2.6	11.0 ± 2.6

Table 3 shows the energy expenditure according to gender and estimated intensity of workday. The average length of workday and average percentage of maximal oxygen consumption sustained during workdays are similar for males and females. Days identified as being intense by participants (males + females) are significantly longer in duration and more intense in terms of the average percentage of maximal oxygen consumption. For women, the total absolute energy expenditure tends to be lower for workdays perceived as being intense. There is no significant difference between males and females or more intense versus less intense days in the percentage of time spent or in the percentage of maximal heart rate working above 100 beats per minute. On the other hand, males significantly expend the total absolute energy expenditure than females during periods above 100 beats per minute.

3.3. Energy expenditure according to school level of students

Table 4. Energy expenditure according to school level taught and estimated intensity of workday

	Teaching level	Lower intensity	Higher intensity	
Average duration of workday (min)	Primary	326.8 ± 78.6	360.8 ± 76.6	$P < 0.05$ between less and more intense day
	High school	339.7 ± 68.6	380.6 ± 56.6	
	College	336.8 ± 88.7	377.6 ± 92.7	
% of VO_2 max (energy expenditure)	Primary	17.6 ± 11.7	21.8 ± 14.6	$P < 0.05$ between less and more intense day
	High school	15.7 ± 6.0	21.2 ± 6.8	
	College	18.0 ± 9.0	24.8 ± 7.6	
kcal·min^{-1}	Primary	2.9 ± 2.2	3.4 ± 2.2	$P < 0.05$ between less and more intense day
	High school	2.7 ± 1.6	3.8 ± 1.8	
	College	3.2 ± 2.2	4.6 ± 2.6	
% of time spent at >100 bpm	Primary	13.2 ± 13.8	15.6 ± 16.6	$P < 0.05$ between teaching levels
	High school	13.6 ± 15.7	23.8 ± 22.6	
	College	9.8 ± 9.0	7.6 ± 7.8	

% of VO_2 max during this period	Primary High school College	59.6 ± 6.0 63.2 ± 6.8 66.6 ± 9.6	60.6 ± 4.6 63.8 ± 6.7 67.0 ± 5.6	$P < 0.05$ between teaching levels

Given the similarity of the energy expenditure expressed as the percentage of maximal oxygen consumption between men and women, the effect of teaching level on the energy expenditure is studied. Table 4 shows the energy expenditure according to school level taught and estimated intensity of workday. For all grades taught, average working time is generally longer on days considered by teachers as being intense. Percentages of maximal and absolute energy expenditure are significantly greater during days perceived as being more intense. Although the average energy expenditure is rather low, physical education teaching is characterized by periods of more intense work. Therefore, based on the raw data for each participant, the percentages of time spent at heart rates higher than 100 beats per minute are computed. Teachers at the college level spent lower percentages of time at heart rates higher than 100 beats per minute but reached higher percentage of maximal oxygen consumption during these periods.

3.4. Energy expenditure according to task

Figure 1 shows the average energy expenditure according to task category. The average work intensity depends on the combination of different tasks performed by physical education teachers. Some tasks require more energy expenditure than others. Therefore, the work intensity increases from office work, supervision and monitoring to mixed participation and, finally, active participation. The number of subjects is not the same for each task since they employ different intervention strategies in comparison to their colleagues. Considering the high between-subjects variability and the similarity of patterns between genders, these data on male and female participants are pooled. Active participation is significantly more energy-demanding than all other classes of tasks, while mixed participation is different from office work only. Moreover, the energy expenditure intensity shows a significant upward trend across the four categories of tasks considered. Figure 2 shows the total energy expenditure according to task category. The total energy expenditure for active participation is higher than that for office work.

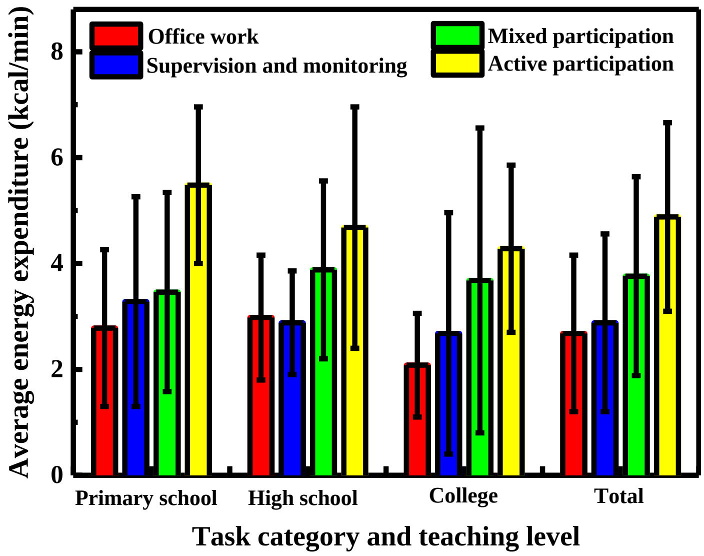

Fig. 1. Average energy expenditure according to task category

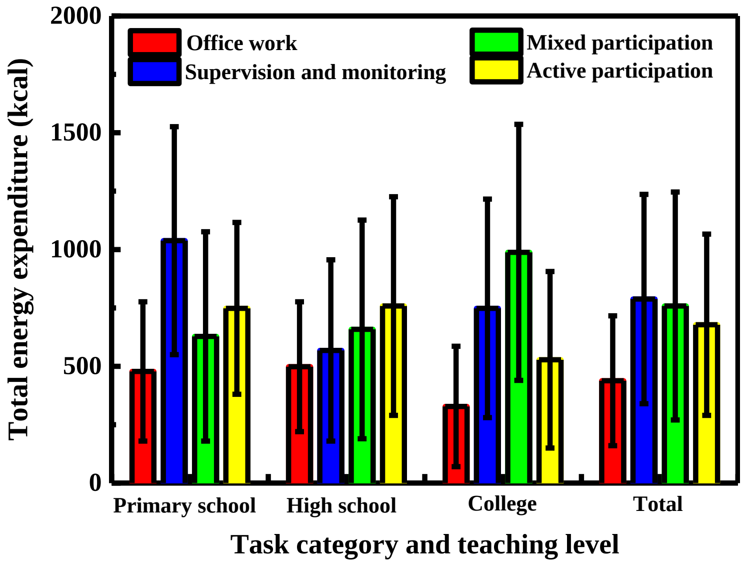

Fig. 2. Total energy expenditure according to task category

4. Discussion

4.1. Participant characteristics and gender differences

In this study, participants are in excellent aerobic fitness. If these data are compared with those of Åstrand *et al.* (1997), participants in this sample have the maximal oxygen consumption, which is similar to Swedish physical education teachers of the same age, either male or female. Additionally, physical fitness of the participants for all other variables is good-to-excellent. With the exception of back extension, the physical fitness of females is similar to that of males. Yet, the physical fitness of males is better than average, except for body composition, where the body mass index is slightly higher than recommended values. However, since their waist circumferences are in the low-risk regime and their percentages of fat have been found to be good, it is likely that this slightly higher body mass index may be attributed to a higher lean mass (Nevill *et al.*, 2010). Therefore, it is reasonable to conclude that physical education teachers are generally in better physical fitness than the average population, regardless of gender and age.

Sandmark (2000) has been found that the energy expenditure of physical education teachers is comparable to occupations with high energy expenditure. In this study, on days identified by them as low-intensity, physical education teachers are working at intensities deemed by Kroemer *et al.* (1997) to be "light/easy", whereas intense days lay between "light/easy" to "medium/moderate", according to absolute values of the energy expenditure.

The relative energy expenditure values averaged over the work shift expressed as the percentage of maximal oxygen consumption can be considered low, with nearly 16.5% maximal oxygen consumption for "easy" days (Rodgers *et al.*, 2004) and nearly 22 % maximal oxygen consumption for "intense" days (Wu and Wang, 2002, Wu *et al.*, 2010). Theoretically, according to these experimental data at an intensity of 28 % of the maximal oxygen consumption, physical education teachers could work for 12 hours. With working times measured for the participants in this study, intensities of 48 and 42 % of the maximal oxygen consumption could theoretically be sustained. Therefore, it appears that work intensity in physical education teachers is quite low on average. The energy expenditure in physical education teachers corresponds to that found in carpenters, bakers, butchers, and coal oven workers (Haerens *et al.*, 2015, Kahan and McKenzie, 2017, Svendsen and Svendsen, 2016). However, a particular characteristic of the profession, which can make it more strenuous than others, is the occurrence of high-intensity periods found during active participation interspersed with low-intensity periods associated with office work or supervision and monitoring. During periods with the heart rate higher than 100 beats per minute, labor intensity averaged 58-66 % of the maximal oxygen consumption for durations of 28-90 minutes spread throughout the day. This is highly variable between participants, each using his/her own combination of tasks to undertake physical education teaching.

It has been found that the acceptable burden of work for an 8-hour shift is about 30-40 % of the maximal oxygen consumption (Åstrand *et al.*, 2003, Bink, 1962, Rodgers *et al.*, 2004, and Saha *et al.*, 1979). This theoretical workload is an average that should be stable. Additionally, an average of 110 beats per minute over a work period of 8 hours should not be exceeded by industrial workers (Brouha, 1967). However, to rely to an absolute value of heart rate without reference to the relationship of an individual between heart rate and oxygen consumption results in an approximate estimation of energy expenditure (Bradfield, 1971, Scott and Kemp, 2005).

4.2. Energy expenditure and teaching at different school levels

Subjective evaluation by Lemoyne *et al.* (2007) has indicated that perceived task load is significantly greater among primary school teachers. In this study, however, objective measurements of the energy expenditure between comparative levels of education invalidate the observations reported in the questionnaire survey of estimated workload. This may also be due to the fact that measures of the energy expenditure do not take into account some subjective factors that may increase the perceived burden of tasks without augmenting heart rate as noise, non-adapted school gymnasiums in primary schools, and assignments in different schools (Mäkelä *et al.*, 2014, Moy *et al.*, 2014, Oliver *et al.*, 2014).

4.3. Energy expenditure and gender

The results, expressed as the percentage of maximal oxygen consumption, indicate similar energy expenditures in male and female participants. When the results are expressed in kcal·min^{-1}, however, there is a slight (but not significant) tendency to higher energy expenditures in males, which can be attributed to their heavier body weight. The hypothesis, the energy expenditure may be higher among women, is reversed when considering the percentage of maximal oxygen consumption as an energy expenditure measure. Energy expenditure expressed as the percentage of maximal oxygen consumption is a better gauge of physiological strain in general and more so if a task requires support of body weight (Åstrand *et al.*, 2003).

The energy expenditure in the literature is typically expressed in absolute values (kcal·min^{-1}) rather than relative values (the percentage of maximal oxygen consumption). However, this approach has several drawbacks. As discussed above, absolute values are slightly higher in men, indicating greater task burden. However, absolute energy expenditure values in males are somewhat higher, which is due primarily to their greater weight. Since the task burden is better represented by the percentage of maximal oxygen consumption, the task of energy expenditure is similar for men and women.

Finally, the energy expenditure cannot be considered as the only measurements of job strain, since many other factors can significantly affect the workload. The working environment is also a factor than can significantly increase the work strain. As an example, it is determined that scheduling and the lack of material resources make the work harder (Mäkelä *et al.*, 2014). Other factors like student behavior or the lack of motivation (Mäkelä *et al.*, 2014) may also impact on the job strain and should be considered when evaluating job strain in physical education teachers.

5. Conclusion

Physical education teachers are a group of workers with a high level of fitness, and particularly aerobic fitness. The data on most fitness variables are very similar for men and women except for back extension and body composition. The physical fitness of physical education teachers in this sample is not affected by age. The energy expenditure of physical education teachers is, on average, low when expressed in relative values as well as low-to-moderate when expressed in absolute values. A weakness of this study is the lack of measurement of tasks requiring sudden and short bursts of muscular contraction that may increase the occupational burden without augmenting heart rate. Finally, high inter-variability and intra-variability in terms of gender, age and education level can be observed because teaching practices greatly vary from one physical education teacher to another and across workdays. If physical education teachers are expected to actively participate with students, good fitness is warranted.

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