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Intermonitor variability of RT3 accelerometer during different activities

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Abstract

Purpose of this study was to analyze reliability and variability of the RT3 accelerometers. The RT3 was administrated to two repeated trials of six activities; rest, two steps, walking, and two running. One person performed all trials (male: age 28 yr, 169 cm, 63 kg). Each activity lasted 12 min. Data were analyzed for activity, monitor, and trial effects. The replacement of monitors also analyzed for left and right side differences and association between heart rate and accelerometer counts was analyzed. A three-way interaction was found for vector magnitude ($F_{35.0}$ = 190732.08 p<0.029) and X ($F_{35.0}$ = 267589.97, p<0.001) and Y ($F_{35.0}$ = 182169.56, p<0.001) and Z axes ($F_{35.0}$ = 815995.11, p<0.001). A two way interaction was found for VM (p<0.002), X, Y, and Z axes (p<0.001). Placement differences between right and left monitors were found for vector magnitude, X and Z axes. At both trials 1 and 2 there was no significant heart rate differences. The Y axis of the RT3 accelerometer was the most reliable in this study. RT3 accelerometer is reliable for physical activity level.

Keywords: Accelerometer; RT3; variability; reliability; heart rate.

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1. Introduction

Physical activity is essential component of healthy life style. There is growing evidence that physical activity is important to the short and long term health of children and adolescents (Sallis, Patrick,1994). Among youth, physical activity is inversely associated with a number of cardiovascular disease, risk factors, including hypertension (Alpert and Wilmore, 1994), elevated blood lipids (Armstrong, and Simons-Morton, 1994; Thorland and Gilliam, 1985), obesity (Bar-Or, Baranowski 1994; Ward and Evans, 1995), and cigarette smoking (Lee, Jung, Park, Rhee, Kim, 2005), while positively associated with physical fitness (Malina, 1995; Moller, Kaufman, 2005), HDL cholesterol (Borodulin et al., 2005; Ekelund et al. 2005), bone mass (Chen, Yang, 2004), and psychological well-being (Calfas, and Taylor, 1994; Chen, 2004). On the basis of this evidence, an expert panel recommended that adolescents be physically active on a daily or near daily basis and complete at least three bouts of continuous moderate to vigorous physical activity on a weekly basis (Sallis, Patrick,1994). These recommendations are outlined in Healthy People 2000 and the ACSM recommendation for physical activity and public health (Pate, 1993).

The measurement of physical activity has been limited by methodological problems (Pate, 1993), but accelerometers may offer a solution to these problems. In order to measure physical activity a three dimensional triaxial accelerometers have been used. The RT3 triaxial accelerometer is relatively small and replaced the TriTrac-R3D as a more researcher and user friendly device (Powell and Rowlands, 2004). To our knowledge accelerometers are acceptable to most children. However, researchers working with middle school students should carefully monitor compliance to ensure that devices are worn properly and regularly.

Powel and Rowland (Powell and Rowlands, 2004) studied on the reliability of the RT3 accelerometers during two trials of six activities: rest; walking, running and repeated sit to stand. In our institute RT3 accelerometers have been used for measure physical activity of children with Intellectual Disability.

The purpose of this study was to investigate the reliability and intermonitor variability of RT3 accelerometers.

2. Material and Methods

2.1. Instrumentation

In order to measure physical activity a three dimensional triaxial accelerometers have been used. The RT3 triaxial accelerometer is relatively small and replaced the TriTrac-R3D as a more researcher and user friendly device (16). All monitors tested were worn at the same time by one participant (male: age 28 yr, height 169.0cm, weight 63 kg) in a laboratory setting.

The RT3 accelerometer: The RT3 is a small (68 x 48 x 18 mm), lightweight (65.2 g), battery-powered monitor. Eight RT3 accelerometers were selected randomly from a sample of 12, which were all 1 year old and previously used in some investigations. The third mode was selected. All RT3 accelerometers were initialized via a computer interface, simultaneously started, and split into two sets of four according to Powel and Rowlands' procedure (Powell and Rowlands, 2004).

Heart rate was measured using a Polar (S610i) HR monitor (Polar Electro Oy, Kempele Finland). The HR monitor was programmed to store the heartbeat every minute, allowing synchronization in time with the accelerometer. After activities, the data were downloaded to computer files.

2.2. Procedure

The reliability and intermonitor variability of RT3 was assessed during two trials of 6 activities: rest, walking (5.2 $km.h^{-1}$ 3 Mets), running (8.4 and 10.5 $km.h^{-1}$: 9 and 11 Mets performed on an electronically driven treadmill (model: LE 200 CE) and two different step activities (height 10 cm, 20 up-down/min., and height 30cm, 30 up-down/min; 3 and 9 METs respectively). Each activity was performed for 12 min. The two trials were performed 2 apart. After each trial, RT3 monitors were removed and data downloaded. The RT3 accelerometers were placed at the same position at each trial. The first and last minute of each 12-min bout was deleted, leaving 10 min at each activity for each trial. Data output were counts per minute (cts-1), (Powell and Rowlands, 2004). All monitors tested were worn at the same time by one participant (male: age 28 yr, height 169.0cm, weight 63 kg) in a laboratory setting (Lippincott & Wilkins, Baltimore 2000.)

2.3. Data Analysis

Descriptive statistics were calculated for each activity at trial 1 and trial 2. Inter-monitor coefficient of variation (CV) for each activity at each trial was calculated. A three-way mixed model ANOVA was performed to examine the inter-monitor variability and reliability of RT3 for each vector. Pearson correlation coefficient was used to obtain association between HR monitor and accelerometer counts.

3. Results

Descriptive data are shown in table 1. Inter-monitor CV showed low variation for all axis (Table 2) during walking and running (<5.2%). However, relatively high variation was evident during step activities (3,4-15,6%). Due to very low mean score at rest the CV was inflated and not considered meaningful, therefore, it is not presented in table 2.

Table 1 Activity by vector descriptive statistics (cts·min^{-1}, beat·min^{-1}mean ± SD)

Trial		Rest	Step 1 3 Met	Step 2 9 Met	5,2 km·h^{-1}	8,4 km·h^{-1}	10,5 km·h^{-1}
VM	1	21,2 ± 28,7	502,0 ± 33,7	1774,6 ±138,5	3247,0 ± 74,7	6343,8 ± 143,0	6575,0 ± 278,7
	2	11,3 ± 28,6	610,8 ± 55,7	1956,3 ± 216,8	2610,8 ± 51,9	5546,6 ± 158,6	5960,4 ± 125,0
X	1	6,9 ± 11,9	320,3 ± 15,1	1173,8 ± 135,9	1210,7 ± 47,7	3058,9 ± 85,0	3399,2 ± 135,2
	2	2,1 ± 5,5	368,1 ± 57,4	1304,3 ± 180,7	1189,6 ± 36,6	3256,3 ± 120,8	3660,1 ± 109,9
Y	1	10,1 ± 13,6	292,3 ± 33,0	972,2 ± 85,0	1799,9 ± 58,2	3181,5 ± 81,1	3223,0 ± 153,3
	2	3,8 ± 9,5	348,9 ± 33,5	1081,3 ± 98,7	1611,7 ± 43,1	2793,4 ± 99,0	2923,9 ± 98,7
Z	1	7,5 ± 6,9	229,9 ± 18,9	825,2 ± 28,4	2350,7 ± 53,6	4332,8 ± 125,0	4420,0 ± 230,3
	2	8,8 ± 23,2	311,4 ± 26,8	913,5 ± 97,0	1590,6 ± 47,8	3387,7 ± 164,0	3603,2 ± 104,2
HR	1	80±5.2	96.3±1.64	160.1±9.5	95.7±1.5	139.2±5.5	161.0±2.7
	2	82.7±6.0	103.2±4.1	161.6±6.2	107.6±1.2	140.8±3.8	161.4±2.7

Table 2 Intermonitor coefficients of variation by activity (CV, %)

Trial		step 3 met	step 9 met	5,2 km.h^{-1}	8,4 km.h^{-1}	10,5 km.h^{-1}
Vm	1	6,7	7,8	2,3	2,3	4,2
	2	9,1	11,1	2,0	2,9	2,1
X	1	4,7	11,6	3,9	2,8	4,0
	2	15,6	13,9	3,1	3,7	3,0
Y	1	11,3	8,7	3,2	2,5	4,8
	2	9,6	9,1	2,7	3,5	3,4
Z	1	8,2	3,4	2,3	2,9	5,2
	2	8,6	10,6	3,0	4,8	2,9

3.1. Vector magnitude

A three way interaction was found ($F35.0 = 190732.08$ $p<0.029$). The significant activity x monitor interactions were found at trial 1 ($F35.0 = 227.02$, $p<0.02$) and trial 2 ($F35 = 181.9$, $p<0.005$, Figure 1). At both trial 1 and trial 2 all activities were significantly different from each other with the exception of 8.2 and 10.5 km.h^{-1} (12% at trial 1 and trial 2, Fig. 2). Within activities, there were no significant differences between monitors at rest, step1 or step2 at trial 1 or trial2. However, as intensity increased (5.2-10.5 km.h^{-1}) in walking and running the intermonitor difference decreased. In opposition to this situation as intensity increased in step exercises (3 Mets- 9 Mets) the inter-monitor difference increased. There was activity X trial interaction (F5.0 = 23.88, p<0.001); however, there was no a monitor x trial interactions. No monitors were significantly different between trial 1 and 2 (Fig. 1).

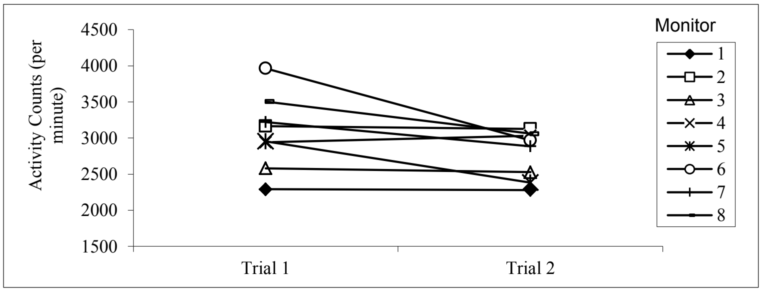

Figure 1. Monitor by trial: vector magnitude (mean ± standard error).

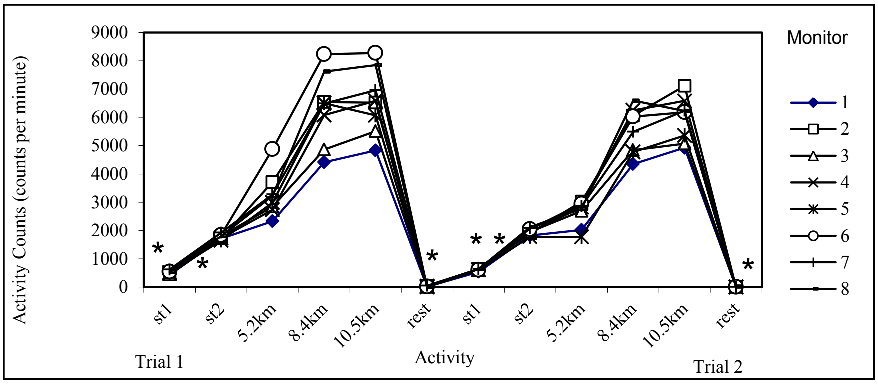

Figure 2. Monitor by activity: vector magnitude (mean ±SEM).

Activities 5.2, 8,4, 10,5 $km \cdot h^{-1}$ step1 and step2.* No significant differences between monitors at rest, or step1,step 2.

3.2. X axis.

A three-way interaction (activity x monitor x trial) was found (F35.0 = 267589.97, p<0.001). The significant activity X monitor interactions were found at trial 1 (F35 = 179.68, p<0.001) and trial 2 (F35 = 160.58, p<0.001). All activities were significantly different from each other with the exceptions of rest, step1 and step 2. However intensity increased the intermonitor difference increased (9-56%, Table 3). Within activities there were no significant differences between monitors at rest. No difference across trials was shown for the X axis (Tables 2-4).

Table 3: Percentage of possible pairings of monitors significantly different within each activity

Trial		Rest	St1	St2	5,2 $km.h^{-1}$	8,4 $km.h^{-1}$	10,5 $km.h^{-1}$
VM	1	0	7	8	10	23	33
	2	0	8	15	12	33	40
X	1	0	9	12	13	23	56
	2	0	10	30	14	46	52
Y	1	0	8	13	13	31	27
	2	0	9	19	13	35	40
Z	1	0	7	14	13	36	35
	2	0	10	17	16	47	38

Table 4: Percentage of possible pairings of monitors that differentiate between activities

Trial		Rest- St1	ST1-St2	St2-5.2 $km.h^{-1}$	5.2 $km.h^{-1}$ -8,4 $km.h^{-1}$	8,4 $km.h^{-1}$-10,5 $km.h^{-1}$
VM	1	100	8	10	23	33
	2	100	15	15	32	40
X	1	100	12	13	23	56
	2	100	30	18	45	52
Y	1	100	13	13	30	30
	2	100	18	19	34	39
Z	1	100	15	15	35	35
	2	100	16	16	47	47

3.3. Y axis.

A three-way interaction (activity x monitor x trial) was found (F35.0 = 182169.56, $p<0.001$). Follow-up two-way ANOVA revealed significant activity x monitor interactions, at trial 1 (F35.0 = 174.92, $p<0.001$) and trial2 (F35.0 = 108.99, $p<0.001$). At both trials 1 and 2, rest and stepping 1 were not significantly different from each other, and a proportion of possible monitor pairings, increasing with intensity, did not differentiate between step1 and step2, step2 and 5.4 $km.h^{-1}$, 5.2 $km.h^{-1}$and 8,4 $km.h^{-1}$, 8.4 $km.h^{-1}$and 10.5 $km.h^{-1}$ (13-39%, Table 1-4). Within activities, there were no significant differences between monitors at rest or stepping 1, for trial 1 or trial 2. There is no differentiating on the inter monitor variability between increasing activities (8-40%, Table 2-3). There was however significant activity X monitor interaction (F35.0 = 7.1, $p<0.001$). No difference across trials was shown for the Y axis.

3.4. Z axis.

A three-way interaction was found (F35.0 = 815995.11, $p<0.001$). Follow-up two-way ANOVA revealed significant activity x monitor interactions, at trial 1 (F35.0 = 171.78, $p<0.001$), and trial2 (F35.0 = 111.13, $p<0.001$). At both trials 1 and 2, step1 and step2, step2 and 5.2 $km.h^{-1}$ were not significantly different from each other, and a proportion of possible monitor pairings, increasing with intensity, did not differentiate between step1 and step2, step2 and 5.2 $km.h^{-1}$ (15-47%, Table 4). Within activities, there were no significant differences between monitors at rest or step activities, for trial 1 or trial 2. However, as intensity increased the inter-monitor variability increased (7-38%, Table 3). There were four monitors that revealed significantly higher activity counts at trial 1 compared with trial 2 (F7.0 = 5.22, $p<0.001$).

3.5. Heart Rate

At both trials 1 and 2 there was no significant HR differences ($p>0.05$). Follow-up one-way ANOVA revealed no significant difference between step1 and 5.2km.h-1, step2 and 10.5km.h-1 ($p>0.05$). However intensity increased HR values increased (step1-step2, 5.2 km.h^{-1}-10.5 km.h^{-1}, $p<0.001$, Table 1).

3.6. Placement

In the comparison with paired test exception of Y axis (2%, $p>0.05$) significantly differences were found between left and right side monitors (12% for VM, 13% for X axes, 33% for Z axes, $p<0.001$, Table 5).

Table 5. Monitor differences between right and left placement.

		Mean	N	Std. Deviation	Std. Error Mean	%	P
Pair 1	VM right	10970,05	120	9073,62	828,30	12%	.000
	VM left	12469,79*	120	10704,95	977,22		
Pair 2	X right	6741,15*	120	5819,67	531,26	12.6%	.000
	X left	5892,35	120	4946,61	451,56		
Pair 3	Y right	6023,55	120	4793,20	437,55	2%	.276
	Y left	6137,77	120	4934,88	450,49		
Pair 4	Z right	5862,05	120	5055,95	461,54	33%	.000
	Z left	8792,15*	120	8282,01	756,04		

* $p<0.001$ significantly higher than the other side monitors

3.7. Energy Estimated

A comparison of total VM counts step activities were found lower than walking and running activities (step1 activity 502±33.7, 5.2 km walking 3247±74,71, step2 activity 1774.6±138.5, 8.4 km running 6343.8±143, $p<0.001$).

Table 6. VM cts^{-1}, HR, and energy expenditure along the activities

Activity	VM cts^{-1}	HR	ACSM Equation (MET)	Powel & Rowlands MET equivelants of RT3 Counts
Step1	502±33.7	99.7±4.64	3	0-2.9
Step2	1774.6±138.5	160.9±7.9	9	3-5.9
5.2 km walking	3247±74,71	101.6±6.2	3	6-9.9
8.4km running	6343.8±143	140.0±4.7	9	>12
10.5km running	6575±278.7	161.2±2.6	11	>12

4. Discussion

After the first study revealed by Powell and Rowlands (Powell and Rowlands, 2004) in this study, we observed that individual RT3 monitors were reliable over trials, with the exception of two monitors on the Z axis. Significant differences were found across trial for monitor 5, and 6 in Z axis. These two RT3 monitors administrated at left side. There is no obvious evidence was found for left side monitors. In our study, RT3 monitors largely differentiated between low level activities intensities (step activities, 3 and 9 Mets), however differentiation decreased as activity intensity increased (8.4-10.5 km.h^{-1}). Considerable inter monitor differences within activities were apparent on all axes. The X axis of motion revealed the least variability between monitors. Due to high variability on the Z axes, the vector magnitude variability was also high.

The vector magnitude (mean count at trial 1 compared with (cf.) trial 2, 3077 cf. 2782 cts.min-1), X (1528 cf. 1630 cts.min^{-1}), and Y (1579 cf. 1460 cts.min^{-1}) axes of motion were shown to be reliable over trials. The Z axis (2027 cf. 1635 cts.min-1) showed no reliability over trials. Fifth and 6th monitors elicited significantly higher activity counts at trial 1 and trial 2 (2220, 3056 cf. 1594, 1907 cts.min^{-1}).

When considering the variability of activity monitors, a range of activity intensities should be considered to adequately test the assumption that the monitor can differentiate between important cut-off points of physical activity.

In the comparison with paired test exception of Y axis (2%, p>0.05) significantly differences were found between left and right side monitors (12% for VM, 13% for X axes, 33% for Z axes, p<0.001). This supports Fairweather et al. 1999 (Fairweather et al 1999), who found significant differences (%3) between left and right hip placements with the CSA uniaxial accelerometer. The effect of the placement of the RT3 (left vs right hip) tested in some plot studies. According to this study no differences were found in activity counts recorded (Powell and Rowlands, 2004; Trost et al, 1998).

The accelerometer counts classified according to the MET equivalents (Powell and Rowlands, 2004). It is important that the different activity counts obtained from step and treadmill which are similar caloric estimated from ACSM equations. In the study Step 1 activity and 5.2 km walking activities has equal as 3 METs, Step 2 and 8.4 km running activities also have equal METs calculated according to ACSM equations (Lippincott & Wilkins, Baltimore 2000). A comparison of total VM counts step activities were found lower than walking and running activities (step1 activity 502±33.7, 5.2 km walking 3247±74,71, step2 activity 1774.6±138.5, 8.4 km running 6343.8±143, p<0.001, Table.6).

Follow-up tests revealed the association for HR and vectoral activity counts (.723 for VM, .717 for X axes, .706 for Y axes, and .740 for Z axes) significant associations were found (p<0.01). There was no significant difference between trails (F= 0.616, p=0.63). The significant associations between heart rate and accelerometer counts were found in many studies (Janz, 1994, Trost et al. 1998).

In conclusion, the anterioposterior axis of the RT3 accelerometer showed the least variability and was the most reliable in this study. It is recommended that inter-monitor and placement variability and reliability of RT3 on each axis be assessed before use. It is revealed that heart rate measurement has higher sensitive results along the activities than accelerometer in this study. The association between heart rate and accelerometer may take in to consideration depending manner of research.

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