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StepWatch accuracy during walking, running, and intermittent activities

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ABSTRACT

Introduction: The purpose of this study was two-fold: 1) to investigate effects of cadence and sensitivity settings for the StepWatch (SW3) on step count accuracy over a wide range of ambulatory speeds, and 2) to compare the preprogrammed "quick start" settings to modified settings during intermittent lifestyle activities.

Methods: Part 1: Fifteen participants (18–57 years of age) performed two trials of treadmill walking and running at ten speeds ranging from 26.8 to 268 m min^{-1} while wearing four SW3 devices. During the first trial, the cadence setting was maintained while sensitivity was varied; in the second trial sensitivity was maintained while the cadence setting was varied. Part 2: Fifteen participants performed four intermittent activities and drove an automobile while wearing two SW3 devices, one with preprogrammed settings and the other with the modified settings determined in Part 1.

Results: Part 1: The modified settings (cadence setting of 70% of default and sensitivity of 16) provided the greatest step counting accuracy across a wide range of speeds reporting 96.0–104% of actual steps between 53.6 and 268 m min^{-1}. Part 2: The preprogrammed settings tended to have higher accuracy for light household tasks (recording 88% to 94% of actual steps) than the modified settings (recording 82% to 86% of actual steps) which showed a trend towards higher accuracy for tennis (recording 93% vs. 89% of actual steps) ($p < 0.05$).

Conclusion: The preprogrammed "quick start" StepWatch settings should be used with individuals who do not engage in running and vigorous sports. However, for individuals who engage in running and tennis, use of modified settings may result in improved step counting accuracy.

1. Introduction

Step counting has been performed for several centuries. Historically, it was used to estimate walking distances (based on an assumed stride length). More recently, however, it has been used to assess ambulatory physical activity in free-living humans. Tryon (1991) has noted that the step can be viewed as a preferred metric for physical activity assessment because it is a natural unit of ambulation. Step counting is an accepted measure of functional status of individuals, particularly at the lower end of the physical activity continuum where walking is the main activity performed and where physical activity questionnaires are less sensitive. For instance, increases in steps per day are viewed as a sign of improvement during the rehabilitation process and they are a valuable metric for discriminating physical activity levels in older adults [1–3]. Additionally, in healthy adult populations, step counters can serve to motivate clients and facilitate behavior change when coupled with a physical activity goal [4,5]. However, these consumer-oriented step counters need to be compared against a more rigorously validated research grade device.

In previous studies, waist-worn pedometers have been found to be reasonably accurate for moderate or self-selected walking speeds (e.g. 80 m min^{-1}). However, few studies have reported step count accuracy during running. Two studies report reasonable accuracy for running speeds including 160–215 m min^{-1}, but accuracy at faster speeds and during intermittent activities is largely unknown [6–8]. Considering the slow speeds involved in intermittent activities of daily living (e.g. cleaning counter tops,

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vacuuming, and dusting) and high speeds involved in sport pursuits (e.g. tennis and basketball) a device that can accurately tally steps over a wide range of speeds is needed for assessing true daily step counts.

The StepWatch 3 (SW3; Modus Health, Inc., Washington, DC) is an ankle-mounted step counter originally developed for use in individuals with impaired functional status [1]. The SW3 is the most accurate pedometer ever constructed for walking, capturing 98% to 100% of all steps taken from 27 to 107 m min^{-1} [9]. Hickey et al. (2015) have shown the SW3 is also quite accurate for intermittent household activities, capturing 90% of steps taken while dusting and 102% of steps taken while cleaning a room. However, a serious limitation of this device is that it only captures 68% of steps during running at 161 m min^{-1} [7]. Other researchers have taken the approach of individualized calibration, adjusting the cadence and sensitivity settings until the device yielded results within 3% of directly observed steps [10,11]. Using this approach, they were able to obtain accurate SW3 results for both walking and running in young children. However, no set rules for practical application were developed.

Clinicians and researchers can program the SW3 to account for the individual user's step characteristics and gait speed. Specifically, the cadence and sensitivity settings preprogrammed into the device can be altered to account for these differences. The cadence setting is the length of time (cadence settings x 0.01 s) after a step is taken during which a subsequent step cannot be counted and sensitivity setting is the threshold acceleration that must be exceeded to register a step [12]. Determining the appropriate cadence and sensitivity settings for different speeds might improve the accuracy of the SW3 during running, while at the same time preserving its high accuracy for walking and intermittent lifestyle activities. Improving the accuracy of the SW3 in able-bodied adults could allow it to be used as a criterion for validating other step counters.

Thus, the purpose of this study was to examine the accuracy of the SW3 for determining steps taken by normal, healthy adults during walking, running, and intermittent lifestyle activities. In Part 1, the impact of the cadence and sensitivity settings on step counting error was explored for treadmill walking/running speeds ranging from 26.8 to 268 m min^{-1}, in order to enhance the

Table 1
Cadence and sensitivity settings for "Easy Start" options.

Quick stepping – No				
Walking speed	Range of speeds	Leg motions	Cadence	Sensitivity
Fast	Regularly engages in both extremes	Fidgety and/or dynamic	59	17
		Normal	59	15
		Gentle and/or geriatric	59	13
		Severely impaired	59	11
	Uses a moderate range of speeds	Fidgety and/or dynamic	64	15
		Normal	64	13
		Gentle and/or geriatric	64	11
		Severely impaired	64	9
	Rarely varies pace	Fidgety and/or dynamic	69	13
		Normal	69	11
		Gentle and/or geriatric	69	9
		Severely impaired	69	7
Normal	Regularly engages in both extremes	Fidgety and/or dynamic	64	17
		Normal	64	15
		Gentle and/or geriatric	64	13
		Severely impaired	64	11
	Uses a moderate range of speeds	Fidgety and/or dynamic	69	15
		Normal	69	13
		Gentle and/or geriatric	69	11
		Severely impaired	69	9
	Rarely varies pace	Fidgety and/or dynamic	74	13
		Normal	74	11
		Gentle and/or geriatric	74	9
		Severely impaired	74	7
Slow	Regularly engages in both extremes	Fidgety and/or dynamic	69	17
		Normal	69	15
		Gentle and/or geriatric	69	13
		Severely impaired	69	11
	Uses a moderate range of speeds	Fidgety and/or dynamic	74	15
		Normal	74	13
		Gentle and/or geriatric	74	11
		Severely impaired	74	9
	Rarely varies pace	Fidgety and/or dynamic	79	13
		Normal	79	11
		Gentle and/or geriatric	79	9
		Severely impaired	79	7
Quick stepping – Yes				
N/A	N/A	Leg motions	Cadence	Sensitivity
		Fidgety and/or dynamic	57	17
		Normal	57	15
		Gentle and/or geriatric	57	13
		Severely impaired	57	11

*When "Quick Stepping – Yes" is selected, "Walking speed" and "Range of speeds" are not available as options in the device software. Cadence and sensitivity settings are based on an individual who is 1.63 m.