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Effects of the center of mass of a stick vacuum cleaner on the muscle activities of the upper extremity during floor vacuuming

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ABSTRACT

Cordless stick vacuum cleaners on the market have two distinctive styles. One with the center of mass (CoM) near user's hand and the other with the CoM near the brush. The main objective of this study was to determine whether the CoM would affect the muscle activities of upper extremity during floor vacuuming. Twenty-four participants conducted floor vacuuming strokes on carpeted floor and tiled floor at two different speeds with a 2.57 kg stick cleaner model with the CoM near its handle and near its brush. The 50th %-ile muscle activities ranged from 5.4% to 16.3% of the maximum activity level (mild to moderate intensity), with significantly greater activities ($p < 0.05$) when vacuuming with the high CoM model. Study results suggest that conventional low CoM stick cleaners are preferable to high CoM stick cleaners to lower physical loads to user's upper extremity muscles for floor vacuuming.

1. Introduction

Floor vacuuming is a routine housekeeping task that involves repetitive manual pushing and pulling of a vacuum cleaner while standing or walking. In a global survey among 28,000 consumers, it was reported that 33% of respondents vacuum 2 to 5 times per week and 46% spend 30 min to 1 h per cleaning (Electrolux, 2013). Previous research that assessed the amount of energy expenditure of vacuuming categorized household floor vacuuming for a short period of time (6–15 min) as 'moderate' intensity physical activity for non-professional females (Bassett et al., 2000; Norman et al., 2003). Vacuuming for 30 min or longer could be a physically demanding household task that needs our attention.

Previously, risks for musculoskeletal problems associated with routine floor vacuuming have been studied for professional vacuuming. It has been reported that vacuum cleaning at work with commercial cleaners poses risks for upper extremity musculoskeletal disorders due to repetitive pushing and pulling motions (Bell and Steele, 2012; Weigall et al., 2005). Although the intensity of physical demands might be less than that of professional vacuuming, household vacuuming may also pose risks for musculoskeletal problems to non-professional users who may be less physically capable than skilled professional janitors (Apostoli et al., 2012).

Current household vacuum cleaners are available on the market in various form factors including canister, upright, robot and cordless stick cleaners. Among them, cordless stick vacuum cleaners cover both portability of hand-held cleaners and floor vacuuming capacity of upright cleaners. Their lightweight and smaller size allows easier maneuvering than heavier upright cleaners, and their versatility enables users to easily convert them into hand-held cleaners for vacuuming tables, sofa or even ceiling. The market share of stick vacuum cleaners by retail unit sales reached 12% in U.S. in 2010 (Energy Star, 2011) and has rapidly increased worldwide (Allen, R., 2017).

Current cordless stick vacuum cleaners on the market have two distinctive layouts depending on the location of the main body. Conventional stick cleaners have their main body near the brush and an extended handle for vacuuming during standing. Since the main body contains major parts such as motor, filter, dust bin and battery, its center of mass (CoM) is positioned near the floor. The other type of stick cleaners has the main body closer to the handle so the CoM is located near user's hand (Fig. 1). The two types of stick cleaners can generate different hand loads and moment on the upper extremity joints during dynamic floor vacuuming motions due to differences in horizontal and vertical forces and moment arms. Since the hand loads and moments are supported by the upper extremity muscles, the two types of cleaners would demand different level of muscle activity during floor vacuuming.

A laboratory experiment was conducted to evaluate the muscle activation level of the upper extremity during floor vacuuming using a stick type cleaner model and to determine which style among the recently introduced high CoM and the conventional low CoM stick cleaners would be more preferable for reducing the upper extremity muscle

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Fig. 1. Examples of a low CoM stick vacuum cleaner (left) and a high CoM stick vacuum cleaner (right).

activity during floor vacuuming. Specifically, this study was aimed to determine the effect of the CoM on the intensity of muscle activities as a function of different floor condition (carpet, tile) and stroke speed (normal, fast) to cover wider usage conditions. Results of this study can be used to help consumers choose a proper vacuum cleaner for their main application and to guide product designers determine the layout or weight distribution of stick vacuum cleaners.

2. Methods

2.1. Participants

Twenty-four young participants (12 females, 12 males) who had no physical difficulty in conducting vacuum cleaning in standing were recruited from the university community (Table 1). All participants had been using vacuum cleaners for their routine housekeeping for at least one year and they were all right-handed. Prior to participating, each participant provided informed consent on a protocol that was approved by the institutional review board.

Table 1
Participant information (mean and standard deviation).

	Age, years	Height, m	Weight, kg
All (n = 24)	20.3 (1.65)	1.67 (0.07)	62.6 (12.0)
Female (n = 12)	20.1 (1.24)	1.63 (0.05)	55.6 (7.52)
Male (n = 12)	20.5 (2.02)	1.73 (0.05)	69.5 (11.7)

2.2. Experimental variables

Independent variables of this study included the location of cleaner's CoM (high, low), floor type (carpet, tile) and stroke speed (normal, fast). Each participant performed cyclic forward-backward floor vacuuming strokes on the two different floors at two levels of stroke speed with a high CoM cleaner model and a low CoM cleaner model. Participants were asked to hold the cleaner's handle using the dominant hand and conduct the vacuuming tasks with the dominant hand only. The order of the eight task conditions (2 CoM locations x 2 floor types x 2 speeds) was randomized and balanced between participants. A short rest break of 1–2 min was provided between consecutive tasks. Dependent variables were the myoelectric activation levels of six upper extremity muscles during the floor vacuuming in each of the eight task conditions.

2.3. Data collection

A high CoM model and a low CoM model were prepared using a wand and a nozzle of a conventional canister-style cleaner with a weight sandbag. A detachable 1.5 kg sandbag was mounted near the handle of the cleaner's wand (64 cm from the bottom of the brush to the center of the sandbag) to simulate a high CoM stick cleaner. For a low CoM condition, the sandbag was mounted near the brush of the wand (13 cm from the bottom of the brush to the center of the sandbag). Total weight with the sandbag and distance between the center of the handle and the floor in vertical standing were 2.57 kg and 74 cm, respectively, and they were similar to that of mean weight and length of existing stick type vacuum cleaners on the market (Fig. 2).

Speed level of pushing and pulling strokes was set at 0.8 m/sec (2 s for a single push/pull cycle) for normal pace and 1.07 m/sec (1.5 s for a single push/pull cycle) for fast pace. The two speed levels were determined according to the results of user observation at a pilot study. Each participant repeated the push/pull cycles for 30 times continuously on a residential cut-pile carpet (18 mm thick) and on a tiled floor by turns. Participants were allowed to employ their natural vacuuming motions based on their experience and preference, but asked to keep both feet on the ground and parallel to each other during vacuuming. Auditory cues (metronome sound) were provided to help the participant keep the pace of the stroke. During vacuuming, the canister cleaner generated consistent suction force through the attached hose, and the weight of the hose was supported by an experimenter to minimize its effect (Fig. 3). Coefficients of friction (CoF) between the

Fig. 2. High CoM model (left) and low CoM model (right), prepared using a canister cleaner wand and a weight sandbag.