Physiological and Perceptual Responses During Household Activities Performed by Healthy Women

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Key Words: activity analysis • work capacity evaluation

Objective. The purpose of this study was to describe the physiological and perceptual responses during two physically demanding household tasks: cleaning the bathroom and vacuuming the living room. It also examined the relationship between predicted aerobic fitness and the physiological responses during the two tasks.

Method. Seventeen healthy women between 30 and 50 years of age volunteered as participants. They were interviewed to gather demographic information required for prediction of aerobic fitness and observed while performing each task for 17 min to 20 min in their own home.

Results. The heart rate, an index of circulatory strain, varied considerably among the participants and was moderately high during both tasks. Vacuuming the living room had a higher level of circulatory strain and perceived exertion than cleaning the bathroom. An inverse relationship existed between the predicted aerobic fitness and heart rate responses during the two tasks.

Conclusion. Routine household tasks result in a significant circulatory strain in healthy women. Persons with high levels of aerobic fitness experience a lower degree of circulatory strain.

The loss of ability to perform one's usual activities after an injury or illness has a great impact on society. Occupational therapists are involved in assessing the person's functional capacity to perform household tasks, in treating persons who have functional limitations in performing household tasks, and in determining compensation for loss of capacity to perform household tasks (Harris, Henry, Green, & Dodson, 1994; Hertfelder & Gwin, 1989; Mathiowetz, 1993; Wilke & Sheldahl, 1985; Wilke, Sheldahl, Dougherty, Levandowski, & Tristani, 1993). For occupational therapists to perform these roles effectively, they need to know the performance demands of these tasks (Foldspang, 1987).

Several authors have noted the importance of household work in society and the lack of data about the physiological demands of household tasks and their interaction with the environment (Allaire, Meenan, & Anderson, 1991; Clark, Czaja, & Weber, 1991; Grandjean, 1973; Smith, 1990; Varghese, Saha, & Atteya, 1994, 1995; Wilke et al., 1995). Initial studies focused on the energy expenditure (Durnin & Passmore, 1967) and heart rate responses of healthy women (Åstrand & Rodahl, 1986) performing various household tasks. More recently, Wilke et al. (1993) compared the metabolic, hemodynamic, and perceptual responses of 65-year-old men with stable coronary artery disease performing a variety of household tasks on the Baltimore Therapeutic Equipment (BTE) Work Simulator1

1Manufactured by Baltimore Therapeutic Equipment Co., New Ridge Road, 7455-L, Hanover, Maryland 21706.
and in a simulated work environment. The authors reported that during vacuuming high-pile and low-pile carpet, there was no significant difference between the two conditions for any of the variables examined. The energy expenditure, which was approximately three times the basal level (i.e., 3 metabolic equivalents), was considered to be light according to established classifications (Astrand & Rodahl, 1986). The authors cautioned against using the heart rate responses recorded on men for women. They also recommended that when using the BTE, it is important to ensure accuracy of body positioning, muscular action, and work pace to replicate task demands during work simulation.

In a subsequent study, Wilke et al. (1995) compared the heart rate, energy expenditure (from oxygen uptake measurements), and rating of perceived exertion (RPE) of healthy women (n = 10) and women with coronary artery disease (n = 26) while they performed four different household tasks. Each activity was performed at a self-determined pace for 6 min or 8 min in a model apartment. The authors reported a significantly lower heart rate response in the women with coronary artery disease than for the healthy women during the changing beds task. This was most likely because these women were on medications (e.g., beta blockers, calcium antagonists), which tend to inhibit the heart rate response. The RPE response in the coronary artery disease group was higher than that observed in the healthy group when scrubbing the floor on hands and knees and mopping the floor. The authors noted the following: (a) The energy expenditure varied significantly among the 10 different activities and reinforced the value of energy conservation during the more intense tasks; (b) instruction regarding pulse monitoring and perceived effort would provide additional guidance for those women who were trying to enhance their role in household activities; and (c) for some persons, the intensity of performing housework was sufficient to induce a cardiovascular training effect, which would be of benefit to persons with coronary artery disease. The authors noted that a limitation of the study was performing the tasks in a model kitchen rather than in the home environment.

It has been well established that persons who exercise regularly and have a high level of aerobic fitness experience reduced cardiorespiratory and perceptual stress when performing at submaximal workloads (Astrand & Rodahl, 1986; McArdle, Katch, & Katch, 1996). Although these observations have been well documented in laboratory studies in which study participants were cycling or walking at a submaximal work rate, data pertaining to the influence of cardiorespiratory fitness on household tasks are limited. Ross and Jackson (1990) validated a nonexercise model for predicting a person's aerobic fitness (maximum oxygen uptake or VO2max) by using simple demographic variables such as age, body mass index (BMI, ratio between mass and the square of the height in meters), and the frequency of participation in physical activity. This model, which was validated on 1,500 men and women, enables researchers who are not exercise specialists to study the role of physical fitness on other aspects of human performance without doing more sophisticated and expensive exercise tests on their study participants. Therefore, the purpose of this study was to (a) describe the physiological and perceptual responses of healthy women performing two common household tasks, namely, cleaning the bathroom and vacuuming the living room, in a natural work environment and (b) examine the relationship between predicted aerobic fitness and the physiological and perceptual responses during these two tasks.

Method

Participants

Seventeen healthy female volunteers between 30 and 50 years of age participated in this research study. A sample of convenience was used. The participants were screened over the phone for health problems and gave their informed consent before participating in the study. They were initially interviewed to obtain specific demographic information necessary for the prediction of VO2max (see the next section), after which they were observed while performing each task in their own home (see Table 1 for participant demographics and Table 2 for participant characteristics).

Pilot Study

Three participants participated in a pilot study to establish the test protocol and identify the two tasks to be analyzed in the main study. The participants were initially presented with a list of five household tasks that met the following criteria: (a) moderate level of energy expenditure (Ainsworth et al., 1993); (b) performed indoors and year-round; and (c) involved a variety of gross motor postures, hand movements, and manipulation of objects. The five household tasks were (a) vacuuming the living room, (b) cleaning the kitchen cupboards, (c) cleaning the bathroom, (d) cleaning the refrigerator, and (e) washing the floors. All three participants selected cleaning the bathroom and vacuuming the living room as the two most demanding; therefore, these two tasks were selected for the main study. For the purpose of this research, cleaning the bathroom included cleaning the sink, toilet, and bathtub; washing the floor; and wiping the mirror. Vacuuming the living room involved removing the vacuum from storage, carrying it to the area of use, vacuuming the living room, moving each piece of living room furniture to vacuum underneath it, and returning each piece of furniture back to its original position.

Prediction of Maximum Oxygen Uptake

During the initial interview, the participants’ age, height, and weight were recorded. They were then asked to complete a Physical Activity Rating (P-AR) scale, using the

code for physical activity described by Ross and Jackson (1990). According to this scale, participation in physical activity is rated from 0 (aversion to physical activity [e.g., driving when it is possible to walk]) to 7 (>3 hr of moderate-intensity physical activity [e.g., running] per week) (see Jackson et al., 1990; Ross & Jackson, 1990, for further details). The P-AR value, along with the participant’s age in years and BMI, was used to predict relative VO₂max (in ml/kg/min), using the following equation: VO₂max = 56.363 + 1.951 (P-AR) - .381 (age) - .754 (BMI). The absolute VO₂max (ml/min) was then calculated from the relative value by multiplying it by the participant’s body weight (in kg).

Procedure

Each participant performed the two tasks on the same day in the privacy of their own home. To address the issue of order effect, the first eight participants performed the vacuuming task first. The order was reversed for the remaining nine participants. For each participant, the heart rate was monitored with a wireless transmitter receiver throughout the test period. The heart rate was stored in the memory of the receiver and subsequently retrieved with computer interface software. These data were then used to calculate the average heart rate reserve (HRR ave %) and maximum heart rate reserve (HRR max %), using the following equations (Rodahl, 1989):

- HRR ave % = [(average working heart rate – resting heart rate)/(age-related maximum heart rate – resting heart rate)] × 100
- HRR max % = [(maximum working heart rate – resting heart rate)/(age-related maximum heart rate – resting heart rate)] × 100

In these equations, the age-related maximum heart rate was calculated using the formula of 220 – age in years (McArdle et al., 1996).

After completing each task, the participant was asked to indicate her RPE on the Borg scale (Borg, 1982). This scale, which ranges from 6 to 20, has been validated against physiological variables such as heart rate and oxygen uptake in healthy persons and has been used extensively in clinical and ergonomic settings. The odd numbers on this scale have the following qualitative descriptors: 7 = very, very light; 9 = very light; 11 = light; 13 = somewhat hard; 15 = hard; 17 = very hard; and 19 = very, very hard. For each task, the participants were asked to identify the central as well as peripheral RPE. This was done to find out whether the perceived stress during the two tasks was due to responses in the heart and lungs (central RPE) or to localized sensations in the muscle groups (peripheral RPE) used to perform the tasks.

Statistical Analysis

Descriptive statistics were used to describe the physiological and perceptual responses during the tasks (Glass & Hopkins, 1984). Paired t tests were used to determine significant differences between the tasks for each dependent variable. Pearson correlation coefficients were used to examine the relationships between predicted VO₂max and heart rate, HRR, and RPE during the tasks. Results were considered to be significant at an alpha level of p ≤ .05.

Results

The participants’ predicted VO₂max is reported in Table 2. It is evident that there was considerable variation in this variable among the participants. The values ranged from 17.4 ml/kg/min to 41.3 ml/kg/min, which, according to Canadian norms (Minister of State, Fitness, and Amateur Sport, 1986), could be verbally described as poor (low) to excellent (high). However, the mean value of 30.1 ml/kg/min for these participants was at the 49th percentile, and the values could be considered representative of the general population for this age group because they seemed to follow a normal distribution pattern.

The physiological and perceptual responses during cleaning the bathroom and vacuuming the living room are presented in Table 3. The minimum and average heart rate...
and the HRR Ave % were significantly higher during vacuuming the living room than during cleaning the bathroom (p ≤ .05). There was no significant difference in the maximum heart rate or HRR Max % recorded during the tasks. Central RPE was significantly higher during vacuuming the living room and cleaning the bathroom. Differences in peripheral RPE between the tasks approached significance (p = .059). There was no significant difference between central and peripheral RPE during either task.

The relationships between the predicted VO2max and heart rate responses during the two tasks are reported in Table 4. It is interesting to note that all the correlations were negative. However, the relative VO2max was significantly related only to the HRR Ave % during both tasks and to HRR Max % during vacuuming the living room. Although these correlations were significant, the variance explained by these relationships ranged only between 28% and 31%.

The relationships between VO2max and the central and peripheral RPE during the two tasks are reported in Table 5. As expected, most of the correlations between these two sets of variables were negative, suggesting that participants with a higher aerobic capacity tended to have a lower central and peripheral RPE. However, only the correlation between absolute VO2max and central RPE during vacuuming the living room was significant. There were no significant correlations between RPE and heart rate for either task.

### Table 3

<table>
<thead>
<tr>
<th>Variable</th>
<th>Vacuuming the Living Room</th>
<th>Cleaning the Bathroom</th>
</tr>
</thead>
<tbody>
<tr>
<td>M (SD)</td>
<td>Range</td>
<td>M (SD)</td>
</tr>
<tr>
<td>Minimum HR (bpm)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>90 (8.2)</td>
<td>70-104</td>
<td>88 (8.8)</td>
</tr>
<tr>
<td>Average HR (bpm)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>105 (10.5)</td>
<td>81-126</td>
<td>101 (10.4)</td>
</tr>
<tr>
<td>Maximum HR (bpm)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>122 (9.9)</td>
<td>99-142</td>
<td>119 (11.1)</td>
</tr>
<tr>
<td>HRR Ave %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30.5 (6.4)</td>
<td>21.8-43.0</td>
<td>26.5 (5.7)</td>
</tr>
<tr>
<td>HRR Max %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>46.7 (9.4)</td>
<td>28.6-65.7</td>
<td>43.7 (8.5)</td>
</tr>
<tr>
<td>Central RPE*</td>
<td>11.8 (1.0)</td>
<td>8.0-14.0</td>
</tr>
<tr>
<td>Peripheral RPE</td>
<td>11.8 (1.4)</td>
<td>10.0-15.0</td>
</tr>
</tbody>
</table>

Note. Age-related maximum heart rate = 220 – age in years; HR = heart rate; HRR = heart rate reserve; RPE = rating of perceived exertion; HRR Ave % = [(average working HR – resting HR)/age-related maximum HR – resting HR)] x 100; HRR Max % = [(maximum working HR – resting HR)/age-related maximum HR – resting HR)] x 100.

*p ≤ .05 for cleaning the bathroom vs. vacuuming the living room.

### Table 4

<table>
<thead>
<tr>
<th>Physiological Response</th>
<th>Vacuuming the Living Room</th>
<th>Cleaning the Bathroom</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Relative VO2max (ml/kg/min)</td>
<td>Absolute VO2max (ml/min)</td>
</tr>
<tr>
<td>Minimum HR</td>
<td>-4152 (0.999)</td>
<td>-2709 (2.293)</td>
</tr>
<tr>
<td>Average HR</td>
<td>-3588 (1.17)</td>
<td>-3111 (2.24)</td>
</tr>
<tr>
<td>Maximum HR</td>
<td>-4700 (0.957)</td>
<td>-2428 (3.348)</td>
</tr>
<tr>
<td>HRR Ave %</td>
<td>-5292 (0.029)*</td>
<td>-3764 (1.136)</td>
</tr>
<tr>
<td>HRR Max %</td>
<td>-5186 (0.031)**</td>
<td>-2743 (2.87)</td>
</tr>
</tbody>
</table>

Note. Age-related maximum heart rate = 220 – age in years; HR = heart rate; HRR = heart rate reserve; VO2max = maximum oxygen uptake; HRR Ave % = [(average working HR – resting HR)/age-related maximum HR – resting HR)] x 100; HRR Max % = [(maximum working HR – resting HR)/age-related maximum HR – resting HR)] x 100.

Discussion

In this study, it was demonstrated that the heart rate, which is considered to be a measure of circulatory strain (Rodahl, 1989), was moderately high during the two household tasks of vacuuming the living room and cleaning the bathroom. Examination of the individual heart rate values during the two tasks indicated that for seven participants, the level of circulatory strain could be considered very heavy according to Rodahl's (1989) classification. Rodahl identified several factors that could influence the physiological responses to work, including task duration, weight and characteristics of equipment used or objects handled, type of work (static, dynamic, combination), and work pace. Some of these factors may have contributed to the difference in heart rate observed between vacuuming the living room and cleaning the bathroom. Both activities required a combination of static and dynamic work. However, the equipment used in the tasks differed. During the vacuuming task, the average weight of the vacuum cleaner was 8.9 kg (range = 6.1 kg-10.4 kg). Ten participants used canister vacuums, five used uprights, and two used central vacuum systems. The participants transported the vacuum from one location to another. Pushing and pulling the vacuum, including the vacuum wand and head, over a carpeted floor increased the effort required to maneuver it. Conversely, during the bathroom cleaning task, the participants used few pieces of equipment that were of minimal weight. This factor was commented on by one participant who rated the peripheral RPE during vacuuming at 15, which is charac-
terized as “hard” on the Borg scale. She stated that she rated the vacuuming task high because of the required pushing and pulling of her heavy upright vacuum (10.4 kg) by her arms. Subtasks were another factor contributing to the difference in the responses between the tasks. For example, participants moved furniture and other heavy objects during vacuuming the living room, whereas this subtask was not a requirement of cleaning the bathroom.

The heart rate and RPE responses reported by Wilke et al. (1993, 1995) were different from those recorded in the present study. In their initial study on older men, Wilke et al. (1993) observed absolute heart rate values that were below those recorded in the present study. This discrepancy could be due to several factors, including (a) nature of the tasks, (b) medications taken by study participants, (c) gender differences, and (d) age. In the present study, the participants performed the tasks for 17 min to 20 min, lifted and carried the vacuum from storage or within their home, pulled and pushed the vacuum over the floor, and moved furniture or other objects. From Wilke et al.’s task description, the study participants worked for a shorter duration and were not required to transport the vacuum or lift objects. Some took medications (e.g., beta blockers, calcium antagonists) that would have lowered their heart rate. The third possible explanation was that men, having more upper body strength than women (Wilke et al., 1993), would not have to work as hard to do the same task. Therefore, they would most likely attain lower absolute heart rate values. However, it should be noted that if the heart rate was expressed as a percentage of the age-predicted maximum heart rate (i.e., 220 – age in years), there was no significant difference in the heart rate reported between the two studies. This was because the men in Wilke et al.’s study were older than the women in the present study.

The absolute heart rate values observed in the present study were lower than those reported for the healthy women in the Wilke et al. (1995) study. It should also be noted that the women in Wilke et al.’s study were older than those in the present study. Because maximum heart rate generally declines with age (Åstrand & Rodahl, 1986), these data suggest that the older women in Wilke et al. were working at a higher percentage of their age-related maximum heart rate. In other words, the degree of circulatory strain in their study participants was higher than that of their younger counterparts in the present study. This difference was particularly evident when the older participants were mopping the floor and scrubbing the floor on their hands and knees—two tasks that were performed by the participants in the present study as subtasks of cleaning the bathroom.

The RPE values reported for the two tasks in the present study are comparable to those documented by Wilke et al. (1993, 1995) for similar tasks. Wilke et al. did not differentiate between the central and peripheral RPE in their studies. The current observations indicate that the central RPE during vacuuming the living room was significantly higher than that recorded during cleaning the bathroom. This was most likely because the heart rate during the vacuuming task was also significantly higher than during the bathroom cleaning task. The Borg scale has been validated against heart rate measurements during a cycling exercise (Borg, 1973). However, the results of the present study did not show significant relationships between heart rate and central RPE during the two tasks. This discrepancy could be due to several factors, including the type of task, the duration of the task, and the time at which the RPE was administered (Borg, 1982; Gamberale, 1985; Kirk & Schneider, 1992). For both tasks, the activity involved use of both the arms and the legs, whereas the RPE scale was developed using only the legs on a bicycle test (Borg, 1973). It is likely that the additional muscle mass used while performing the tasks in the present study could have altered the relationship between heart rate and RPE (Shephard, Bioulet, Vandewalle, & Monod, 1988). Kirk and Schneider (1992) found that for the same tasks, the RPE increased as the duration of the activity increased. Although both tasks were performed for the same duration in the present study, they were performed for fairly long periods (approximately 17–20 min), and it is possible that this extended duration could have influenced the present RPE values. During this study, the RPE was administered at completion of the task. It is also possible that if the RPE had been administered during the task, different values may have been recorded.

It is generally accepted that there is an inverse relationship between VO_{2max} and the submaximal heart rate response during physical work (Åstrand & Rodahl, 1986; McArdle et al., 1996). However, data confirming this relationship during household tasks are limited. The results of the present study (see Table 4) demonstrate that the relationship between these two variables is valid in this setting, implying that the circulatory strain is lower in persons who

<table>
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<tr>
<th>Variable</th>
<th>Cleaning the Bathroom</th>
<th>Vacuuming the Living Room</th>
<th>Cleaning the Bathroom</th>
<th>Vacuuming the Living Room</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative VO_{2max}</td>
<td>−16.22 (−0.534)</td>
<td>−29.83 (−0.253)</td>
<td>−14.86 (−0.569)</td>
<td>−28.16 (−0.275)</td>
</tr>
<tr>
<td>Absolute VO_{2max}</td>
<td>−22.27 (−0.390)</td>
<td>−55.16 (−0.022)</td>
<td>−16.35 (−0.531)</td>
<td>−23.00 (−0.374)</td>
</tr>
</tbody>
</table>

Note. RPE = rating of perceived exertion; VO_{2max} = maximum oxygen uptake. *p < .05.
have high levels of aerobic fitness. These observations are consistent with the findings of Åstrand (as cited in Grandjean, 1973) and Stübeler (as cited in Grandjean, 1973) who concluded that heart rate values during household activities were high and inversely related to the fitness level. However, it should be noted that the variance ($r^2$) between these two variables in the present study ranged only between 28% and 31%, suggesting that factors other than aerobic fitness also influenced the degree of circulatory strain during these tasks. Åstrand and Rodahl (1986) stated that persons usually self-regulate themselves in their work pace and that their selected work rate and spacing of rest breaks was a reflection of their aerobic capacity. It is possible that the modest correlations observed during the household tasks in the present study were because the tasks, although performed continuously for 17 min to 20 min, consisted of several subtasks that were intermittent in nature. The short breaks between the subtasks seemed to alter the heart rate response, which could have affected its relationship with the predicted $VO_2_{max}$.

One of the factors that could have confounded the present findings is that the heart rate and RPE responses were not recorded during standardized tasks but, rather, were observed in the participants' homes. It is evident from Table 1 that the size and type of home of the 17 participants varied considerably. The size of the living rooms to be vacuumed and bathrooms to be cleaned was also different. These factors most likely influenced the results. On the other hand, the advantage of testing the participants in their own home minimized the anxiety of dealing with an unfamiliar environment and using instruments to which they had not been accustomed.

Implications for Occupational Therapy

The results of this study indicate that the circulatory strain during common household tasks, such as vacuuming the living room and cleaning the bathroom, is relatively high in healthy women between 30 and 50 years of age. Occupational therapists can use this information to screen clients who may be at risk for cardiovascular disorders by recognizing that these routine chores may place excessive stress on a physiological system that may be vulnerable. The fact that the circulatory strain was lower in persons with higher levels of aerobic fitness provides therapists with a strong, scientific rationale for incorporating aerobic conditioning programs into their clients' daily routines. Wilke et al. (1995) made a similar recommendation in their study of older women performing household activities. An example of such an exercise regime is found in Powers and Howley (1990, p. 339). Additionally, advocacy for lifestyle change could form a part of the health promotion or rehabilitation program (LettS, Fraser, Finlayson, & Walls, 1993).

Direct measurement of $VO_2_{max}$ requires specialized, expensive equipment and highly trained personnel to administer and interpret the test results. Moreover, these maximal tests, which are highly stressful, could place even the apparently healthy person at risk for a cardiovascular event. The nonexercise model to predict aerobic fitness (Jackson et al., 1990; Ross & Jackson, 1990) is an invaluable tool that occupational therapists can use in practice to monitor their clients' fitness level. Although it is recognized that this model needs to be validated in a variety of client populations, its current use in healthy persons plays an important role in establishing a database in this area.

Heart rate monitors are inexpensive, practical tools that the clinician can use to gain additional objective information. Routine heart rate monitoring could also be used as a way for persons to gauge their own physiological response to the activity and pace themselves accordingly. Because of the lack of a relationship between heart rate and RPE during household tasks, the use of RPE to predict the heart rate response to an activity is not recommended in the household setting. Alternatively, the RPE may be used in conjunction with heart rate to train a client in gauging his or her activity intensity (Morrison, Barnett, & Hale, 1992) and increase his or her functional status (Wilke et al., 1995).

In establishing the validity and reliability of the BTE, Kennedy and Bhambhani (1991) reinforced the importance of having a good task description in order to set up a work simulation setting. The present study provides limited data pertaining to the heart rate, HRR, and RPE values for two common household tasks in healthy middle-aged women. Therapists can use this information to establish the intensity of a graded treatment program in a work simulation setting. For example, when treating a client whose occupational role involves vacuuming, the therapist may use the BTE to simulate this task in the treatment setting. While monitoring the client's progress in the treatment program and the responses to task demands, the therapist could gradually adjust the intensity of the work simulation program to more accurately reflect the actual task demands. For example, adjustments could be made to the frequency of repetitions, amount of resistance on the BTE, and duration of the treatment session in order to maximize the efficacy of the rehabilitation program.

Conclusion

This study contributes to the scant body of knowledge on the physiological demands of two household tasks: vacuuming the living room and cleaning the bathroom. The results indicated that the heart rate response was moderately high and that some of the healthy participants experienced a high degree of circulatory strain while performing these tasks. The heart rate and central RPEs for vacuuming the living room were significantly higher than those for cleaning the bathroom. A strong inverse relationship was observed between aerobic fitness and the heart rate response in the participants during both tasks, implying that circulatory strain is significantly lower in persons who were more aerobically fit. These findings have important
implications for occupational therapists working in the areas of health promotion, rehabilitation programming, work simulation, and evaluation of functional capacity.

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References


