Original Article

The "Invisible" Cardiac Load: Discordance Between Step-Based and Heart Rate–Based Activity Metrics in Indian Homemakers

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Abstract

Background: Conventional rules on physical activity focus on the number of steps, and the 10,000 steps/day standard is an international norm for cardiovascular health maintenance. Nevertheless, when applying to low- and middle-income countries (LMICs) such as India, domestic labor performed by homemakers entails high levels of isometric stress, floor work, and repetitive upper-body movements, which imply isometric and upper-limb stress. Accelerometers placed on the wrist sometimes do not capture these high-energy-expenditure activities as steps, leaving this population group classified as sedentary despite high physiological requirements. The objective is to determine whether Step Count or Personal Activity Intelligence (PAI), a heart rate-based measure of physiological workload, more closely predicted the physiological workload of Indian homemakers than sedentary corporate workers, and whether or not the cardiovascular workload in the home environment is significantly underestimated using step counts. **Material and Methods:** In this cross-sectional survey, 60 participants (30 homemakers, 30 corporate workers) were tracked using Amazfit wearable devices with tri-axial accelerometers and photoplethysmography (PPG) sensors. Wearable devices were used to monitor participants for 7 days of unfiltered time. The selected primary outcomes included Mean Daily Step Count, Mean Daily PAI score, and Heart Rate Zone distribution. **Results:** The homemakers were walking much less than the 10,000-step reference group (Homesteps: 4,200 ± 850 vs. 3,100 ± 600), but had much better PAI results (Homesteps: 115 ± 18 vs. 35 ± 12; $p<0.001$). Although homemakers with 80% "Sedentary" indicated in number of steps (less than 5000 steps), 73% of residential homesteaders were in the PAI category (more than 100 PAI). Heart rate variability analysis indicated that domestic chores elicited moderate-to-vigorous heart rate responses (100-135 bpm) that were normally associated with aerobic exercise, although there was no increase in steps. **Conclusion:** The estimate of the number of steps greatly undermines the amount of physical activity that Indian homemakers engage in. Measurements of heart rate, such as PAI, have provided a more reliable measure of the invisible domestic physical activity, revealing that this population group has a heavier workload on the heart than previously anticipated. These results reveal the need to revise physical activity recommendations for populations engaged in non-ambulatory and manual labor.

Keywords: Cardiovascular Load, Indian Homemakers, Personal Activity Intelligence, Physical Activity Assessment, Wearable Devices.

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Introduction

India has a high rate of CVDs as a major cause of morbidity and mortality, with an estimated 28 percent proportion of all deaths caused by the condition, and with affected individuals being younger than their counterparts in the Western population.[1] Physical activity (PA) is an established, modifiable risk factor that provides large protection against ischemic heart disease and stroke. Nevertheless, quantifying physical activity in the Indian context poses methodological challenges.[2]

The 10,000 steps per day heuristic in public health recommendations has generally been based on an estimate of physiological rather than ambulatory activity, which is only weakly physiologically validated and whose use is mainly dependent on ambulatory activity. Although step counts are an appropriate proxy for walking, they cannot measure the non-ambulatory physical work (homemakers) of a large group of people in India, whose non-ambulatory and household work cannot be mechanically or physiologically treated as a standard gait cycle.[4]

Indian domestic work also has distinct ergonomic and biomechanical requirements, which differ from those of ambulatory exercise. Activities of routine household tasks entail prolonged, isometric muscular contractions and upper-limb dominant dynamic effort, which generate substantial cardiovascular load but very little lower-limb mass change, and thus are conveniently identified by accelerometry-based step counters.[6] Physiologically, these tasks are in contrast to walking, which is chiefly an isotonic, rhythmic aerobic task that involves cyclical acidic movement of the center of mass, and therefore are easily recognized via an accelerometer-based step counter.

Prolonged stationary postures and exercise performed with

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upper body effort will activate the exercise pressor reflex in domestic labor and therefore produce disproportionate increases in heart rate and blood pressure in relation to oxygen consumption.[7] When the arms are vigorous motions with a strongly stationary lower body, the action is perceived as non-gait, leading an exercise pressor reflex response but metabolic demand without any increment of the count as steps by wrist-worn devices designed to filter non-gait arm movements selectively.[8]

This, in turn, creates a significant measurement gap, in which step-based measures treat long-duration moderate-to-vigorous domestic activity as sedentary. This oversimplification is comparable to the mainstream idea of invisible labor, in which the physical cost of domestic work is undervalued, leading to improper clinical taxonomization and incorrect physical activity prescriptions.[9]

To address the limitations of step-based physical activity assessment, the Personal Activity Intelligence (PAI) metric has been proposed. PAI is a personalized, heart rate–derived score developed by the Cardiac Exercise Research Group at the Norwegian University of Science and Technology. It is calculated using age, sex, resting heart rate, and estimated maximal heart rate, integrating the intensity and duration of heart rate elevation over a rolling 7-day period. Unlike step counts, which rely on movement detection, PAI reflects the physiological response to physical exertion.[10]

Evidence from the HUNT Fitness Study, which followed more than 45,000 individuals over 25 years, demonstrated that maintaining a weekly PAI score of ≥100 was associated with a 25% reduction in cardiovascular mortality, independent of traditional step-count or time-based activity recommendations.[11] By prioritizing cardiovascular intensity rather than ambulatory movement, PAI has the theoretical advantage of capturing non-ambulatory physical activity that is underestimated by accelerometer-based devices.

Study Rationale and Objective

Although PAI has been validated in large Western cohorts, its applicability within the context of Indian domestic labour has not been systematically evaluated. Given the distinct biomechanical and physiological characteristics of household work, it is necessary to determine whether heart rate–based metrics more accurately reflect the cardiovascular workload of Indian homemakers than step-based measures.

The present study aimed to compare the efficacy of step count and Personal Activity Intelligence (PAI) in quantifying physiological workload among Indian homemakers relative to sedentary corporate professionals. The hypothesis was that homemakers would show greater dissociation between low step rates and high PAI scores, indicating that heart rate-based measures are better at determining domestic physical activity than pedometer-based measures.

Materials and Methods

This was a cross-sectional, observational comparative study conducted among adult females living in the state of Tamil Nadu, South India. The measure was aimed at promoting free-living physical activity rather than lab simulations, where the activity is habitual for the participant. The data collection was conducted over 10 weeks between January and March 2024, since this is the time of year when the weather is so hot, a factor that would affect heart rate responses on its own.

The research protocol was aligned with the ethical principles outlined in the Declaration of Helsinki and approved by the Institutional Ethics Committee (IEC). All the participants were informed and provided their written consent before participation.

A pilot power analysis was used to determine a sample size of 60 females to achieve a medium effect size (Cohen d = 0.5) in Personal Activity Intelligence (PAI) scores, with 80% statistical power and a significance level ($\alpha = 0.05$). Purposive sampling and stratification by occupational profile were used to recruit participants into two groups.

1. **Group A: Homemakers (n=30)**

Operational Definition: Women 25 to 45 years old: Women were mainly involved in household management, carrying out fundamental household activities without full-time domestic help, and had to spend at least 4 hours a day on manual household tasks.

2. **Group B: Professionals in a Corporation (n=30)**

Operational Definition: Women between the ages of 25-45 years working in full-time and desk jobs, which entail the presence of very sedentary jobs but limited involvement in everyday household activities.

Inclusion Criteria

- Female participants, 25 45 years old.
- Android smartphone or iOS smartphone that can be used with the Zepp application.
- The possibility of matching the wearable device with the smartphone.
- oloes to wear a monitoring device on a 24-hour basis.
- Ready to undergo consistent monitoring during 7 days.

Exclusion Criteria

- History of cardiovascular disease
- Presence of cardiac arrhythmias (e.g., atrial fibrillation)
- Hypertension (blood pressure >140/90 mmHg)
- Ischemic heart disease
- Use of medications affecting heart rate (e.g., beta-blockers, calcium channel blockers, other chronotropic agents)
- Pregnancy
- Lactation
- Dermatological conditions or wrist lesions preventing continuous wearable device use

The research used the commercially available wearable device, the Amazfit Helio Strap (Huami Corporation), because it supports Personal Activity Intelligence (PAI), a heart rate-based measure of cardiovascular response rather than the number of steps. The computation of PAI is performed automatically by proprietary algorithms that consider age, sex, resting heart rate, and estimated maximal heart rate. The gadget has photoplethysmography to continuously monitor heart rate and a multi-axis accelerometer to track motion and steps. Previously tested experiments show that PPG-derived heart rate is perceived as more acceptable than electrocardiography, even

during light-to-moderate exercise. However, the accuracy of the steps during non-ambulatory tasks remains a weakness.
Constant cardiac rate data were obtained every one minute. PAI was determined cumulatively using a rolling 7-day window, similar to algorithms based on the HUNT Fitness Study. Fittings were attached to the wrist that was not dominant enough to reduce motion artefacts.
Sequential recruiting was used to recruit participants in 10 weekly rounds of six people (three homemakers and three corporate workers) over 10 weeks due to device unavailability. Anthropometry, 10 minutes of supine rest, after which the baseline was assessed (Day 0), and the demographic and medical history were collected. Machines were installed alongside smartphones, with standardized guidelines for use, charging, and synchronization.
Participants wore the device for 24 hours on Days 1 and 7, and carried on with their normal routine to reduce the Hawthorne effect. An activity log, simplified to facilitate correlation between activity variation and heart rate on a daily basis, was maintained. Day 8 involved collecting the devices and extracting data on step counts, heart rate parameters, and the final PAI weekly scores.
The main analysis focused on the dissimilarity between step-based and heart rate-based physical activity categories. Mean daily number of steps and overall PAI score weekly were the primary factors. The secondary outcomes included mean daily time in predetermined heart rate zones, expressed as percentages of estimated maximum heart rate (220-age). The reference for resting heart rate was obtained from a 7-day sleep period recording.
IBM SPSS Statistics version 26.0 was used to do statistical analysis. The data status was assessed using the Shapiro-Wilk test. Continuous variables were reported as means ± SD, whereas categorical variables were reported as frequencies and percentages. Appropriate t-tests, treating independent variables and dependent variables to test differences between the two samples were independent-samples t-tests, chi-square tests, and Pearson correlation analysis, and one considered statistically significant was $p < 0.05$.

Results

Of the 60 participants who attended the monitoring protocol, data from all were included in the final analysis. There was no significant difference in the baseline demographic and physiological features of the two groups. The resting heart rate among homemakers was significantly higher than among corporate workers ($p = 0.04$). There were no notable between-group differences in age, body mass index, estimated maximum heart rate, or time spent wearing the devices per day (Table 1).

Table 1: Demographic and Baseline Characteristics

Characteristic	Homemakers (n=30)	Corporate Professionals (n=30)	p-value
Age (years), Mean ± SD	34.2 ± 5.4	33.8 ± 4.9	0.76
BMI (kg/m²), Mean ± SD	26.4 ± 3.8	25.9 ± 4.1	0.62
Resting Heart Rate (bpm), Mean ± SD	76 ± 8	72 ± 7	0.04*
Estimated Max HR (bpm), Mean ± SD	185.8 ± 5.4	186.2 ± 4.9	0.78
Device Wear Time (hrs/day)	23.1 ± 0.8	22.8 ± 1.1	0.21

Correlation analysis showed that there were dissimilar relations between the number of steps and PAI among groups. With PAI, a significant positive correlation was found between the number of steps taken and corporate professionals ($r = 0.72$, $p< 0.001$). On the contrary, the number of steps and PAI had weak and statistically non-significant correlation in homemakers ($r = 0.24$, $p = 0.18$). [Table 2].

Table 2: Comparison of Activity Metrics

Metric	Homemakers (Mean ± SD)	Corporate Professionals (Mean ± SD)	p-value
Mean Daily Step Count	4,200 ± 850	3,100 ± 600	<0.001
Weekly PAI Score	115 ± 18	35 ± 12	<0.001
PAI per 1000 Steps Ratio	27.4	11.3	<0.001

Activity classification varied depending on the metric used [Table 3].

Table 3: Activity Classification Based on Step Count and PAI Criteria

Classification Standard	Homemakers Classified "Active"	Corporate Classified "Active"
Step Count Criteria (>10,000 steps)	0% (0/30)	0% (0/30)
Step Count Criteria (>5,000 steps)	20% (6/30)	3% (1/30)
PAI Criteria (>100 Weekly PAI)	73% (22/30)	0% (0/30)

The average and intense heart rate ranges were considerably more in household workers than in the corporate workers. There was no significant difference in the time in the highest intensity zone. [Table 4].

Table 4: Mean Daily Time Spent in Heart Rate Zones

Heart Rate Zone	Homemakers (min)	Corporate (min)	Significance
Moderate Intensity (50-69% Max HR)	145 ± 35	45 ± 15	p<0.001
Aerobic (70-84% Max HR)	42 ± 12	10 ± 5	p<0.001
Anaerobic (≥85% Max HR)	5 ± 3	1 ± 1	p=0.08

The qualitative comparison with the list of participant activities related to the time when heart rate levels were high revealed that the time when this process was observed among homemakers was often associated with common household activities, such as manual washing of clothes, sweeping or mopping, and food preparation. Corporate people also recorded slow heart rate increases, but these were uncommon and associated with short time intervals, such as commuting or climbing stairs.

Discussion

The current paper demonstrates a clear dissociation between movement and physiological indicators of sport among Indian homemakers. Even though the homesteaders had much higher mean daily step counts than corporate workers, the mean step count and the Personal Activity Intelligence (PAI) did not show a significant positive relationship in this group. In contrast, corporate workers showed a positive relationship, with the mean step count being highly significant.

The homemakers showed notably elevated resting heart rates, higher weekly PAI ratings, and a considerable duration at moderate and aerobic heart rates. These results imply that step counts are insufficient to describe the cardiovascular costs of everyday homemaking, consistent with the accumulating literature suggesting that phase-based step measures may not provide a reasonable estimate of free-living physiological activity. Wearable activity monitors that rely on accelerometer-derived step counts are limited by their focus on rhythmic, ambulatory movement. Step counts often fail to capture static and upper-body activities that elevate cardiovascular demand, such as squatting, lifting, sweeping, and manual washing, which were commonly reported in homemakers' activity logs. A recent study by Doherty et al.12 found that step-count metrics do not fully reflect non-locomotor activity and that accelerometer measures can underestimate overall physical activity energy expenditure when movements are not step-based.

Heart rate–based metrics, such as PAI, overcome some of these limitations by quantifying physical activity based on cardiovascular response rather than movement alone. In large longitudinal cohorts, a weekly PAI score ≥100 has been consistently associated with lower cardiovascular and all-cause mortality. In the China Kadoorie Biobank study by Wang L et al,[13] participants with ≥100 weekly PAI had lower risks of cardiovascular disease and all-cause mortality, with substantial gains in life expectancy compared with inactive individuals.

Similarly, Nauman et al,[14] reported that achieving ≥100 weekly PAI was associated with a 21% lower risk of all-cause mortality and a 30% lower risk of cardiovascular mortality over 14.5 years in a large U.S. cohort. These findings support the physiological relevance of heart rate–integrated metrics in capturing meaningful activity intensity linked to health outcomes.

Brown et al,[15] noted key considerations when using heart rate–based estimates from consumer wearables, including the need to interpret heart rate relative to individual and contextual factors. Contemporary research has highlighted important limitations of step count and related accelerometer-derived metrics. Chevance et al,[16] provided evidence that combined Fitbit sensor devices inaccurately and systematically estimate heart rate and steps relative to physiological measures, suggesting that it is difficult to measure physiological effort in any meaningful manner through movement-based sensors alone.

Even then, a critical aspect of learning to handle high physiological workload through household work remains. Recent literature has created a paradox of physical activity: formal or habitual physical activity, marked by sustained immobile postures, repetitive manual motion, and insufficient rest intervals, is unlikely to confer the same cardiovascular protection as structured leisure-time exercise. Vigorous cardiovascular exercise, as evidenced by heart rate measures during no-recovery intervals, could, in certain instances, lead to long-lasting strain. Even though we did not actually quantify long-term outcomes, the observation of increased resting heart rate in homemakers could support the hypothesis of long-lasting sympathetic stimulation or an insufficient recovery, which should be labeled as a hypothesis to be explored in further longitudinal research.

Additionally, a cross-sectional study of 2025 by Huang et al,[17] showed that total activity measures from wearables were associated with desirable cardiometabolic outcomes. In contrast, isolated elevation measures were not consistently associated with better cardiovascular phenotypes, underscoring the importance of multidimensional activity measurement.

The evaluation of physical activity in populations with a non-ambulatory work pattern should therefore not focus on the number of steps, as used by clinicians and practitioners in health services. The use of heart rate-based and integrated measurements will be more acceptable for assessing actual physiological workload and enhancing the accuracy of activity monitoring and intervention planning. Wearable technology must move towards multimodal measurement, combining cardiovascular measures with movement to provide a more comprehensive view of usual physical activity.

Strengths and Limitations

One of the strengths of the recently developed study is the emphasis on an underreported population and the possibilities of continuous, free-living physiological monitoring 7 in a row. The step-based and heart rate-based measurements are compared within the same individuals, providing an excellent framework for analyzing measurement discordance.

Nevertheless, several constraints should be considered. The sample was rather small, limiting generalizability. The research used consumer-grade wearable devices, which, although verified for general heart rate measurement, are subject to motion artefacts during active upper-limb movement. Lastly, the cross-sectional design does not allow the researcher to conclude long-term cardiovascular outcomes.

Conclusion

The present paper indicates a significant difference between the measurement of physical activity in terms of steps and that

based on heart rate among Indian-descent homemakers. Although most participants were categorized as sedentary based on the number of steps taken, the PAI scores derived from heart-rate measures of activity indicated substantial cardiovascular work, in line with levels of activity that protect against health-related risks. These results indicate that there is an invisible cardiac load of domestic labor that traditional step-based measures cannot reflect.

Employing physiologically-based measures of physical activity, such as those that assess activity via heart rate, would enhance the validity and fairness of physical activity assessment in non-ambulatory occupations. It is important to acknowledge the cardiovascular risks of household work so that comprehensive public health policies can be developed and women who are likely involved in millions of domestic jobs can be prevented from being misclassified.

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Conflicts of interest

There are no conflicts of interest.

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