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Physical activity and sedentary behavior in peritoneal dialysis patients: a comparative analysis of ActiGraph GT3X data collected via wrist and waist with placement-specific cut-points

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Abstract

Background The increasing adoption of accelerometers for the assessment of sedentary behaviour and physical activity among dialysis patients demands robust validation of these monitoring devices. This study aims to determine the comparability of wrist- versus waist-worn ActiGraph GT3X accelerometers, using placement-specific cut-points for peritoneal dialysis patients, to refine research and clinical practices.

Methods This was a cross-sectional study. Thirty-one participants wore two ActiGraph GT3X accelerometers, positioned on the right waist and nondominant wrist, and monitored over a seven-day period in a naturalistic setting. Data were processed with ActiLife v6.13.3 and analysed using intraclass correlation coefficients (ICC), limits of agreement, and pairwise 90% equivalence test within a ± 10% threshold.

Results The sedentary time measurements from both wrist- and waist-worn GT3X accelerometers were deemed equivalent, with high ICC values (0.98, 95% confidence intervals (CI) 0.97–0.99) and a ratio of 1.0 within the 90% CI of 0.9 to 1.0. Although agreement between accelerometers was good for classification of light-intensity activity (ICC = 0.76), the waist-worn device's estimates exceeded the equivalence criteria compared to the wrist-worn device (ratio 1.4; 90% CI 1.2–1.6). Conversely, the waist-worn device reported a significantly lower duration of moderate-to-vigorous physical activity (MVPA) than the wrist-worn device (Ln transformed ratio 0.3; 90% CI 0.1–0.4).

Conclusions The use of placement-specific cut-points did not ensure equivalence in physical activity parameter estimates between wrist- and waist-worn ActiGraph GT3X devices. The findings underscore the necessity for consistent accelerometer placement for reliable monitoring of physical activity in peritoneal dialysis patients.

Clinical trial number Not applicable.

Keywords Physical activity, Sedentary, Peritoneal dialysis, Accelerometer

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Background

The maintenance of adequate physical and mental capacity is essential for peritoneal dialysis (PD) patients to effectively manage their home-based treatments. Given that physical activities of varying intensities have been demonstrated to enhance physical fitness, integrating activity into daily routines could offer a flexible strategy to support physical capabilities of PD patients [1]. Despite the widely recognised health benefits of an active lifestyle, individuals undergoing PD for end-stage renal disease frequently exhibit inactivity, with 92% classified as "insufficiently active" [2]. For these patients, light physical activities constitute the majority of their daily movements. The International Society for Peritoneal Dialysis and the Global Renal Exercise Network has recently advocated that even marginal increases in daily physical activity and reductions in sedentary time could confer health benefits to PD recipients [3]. Thus, precise measurement of both structured physical activities and routine daily movements is vital for the development and assessment of interventions aimed at addressing the inactivity epidemic.

To mitigate the bias inherent in self-reported activity levels [4], accelerometers have gained popularity for their ability to objectively evaluate physical activity and sedentary behaviour. These devices capture the intensity, duration, and frequency of physical movements in a time-stamped format, providing insights into daily movement patterns. Raw accelerometer data is typically recorded in counts, which must be converted into meaningful energy expenditure or activity intensity categories for interpretation. The literature offers various count cut points for accelerometers, which are also specific to the device's placement site [5].

The ActiGraph is a widely utilised accelerometer for physical activity monitoring in research [6]. It can be positioned at different body locations, most commonly at the wrist or waist. While large epidemiological studies have traditionally employed waist-worn accelerometers [7, 8], wrist-worn devices offer convenience and comfort, enhancing patient compliance over extended wear periods [9]. Moreover, wrist-worn accelerometers are capable of capturing arm movements associated with non-ambulatory activities, such as household chores [10].

Previous research has compared waist- and wrist-worn accelerometers in naturalistic settings, revealing good agreement in the classification of moderate-to-vigorous physical activity [11], yet discrepancies have been noted in the assessment of low-intensity domestic tasks [12]. The choice of cut-point methods for determining sedentary time and activity intensity may influence the compatibility of accelerometer data across different wear locations. Although Montoye et al. [13] have established vector magnitude cut points for activity intensity classification from a non-dominant, wrist-worn ActiGraph in a free-living context, a comparative analysis of activity parameters measured by waist- and wrist-worn accelerometers, utilising respective cut points, is lacking. The objective of this study was to compare activity parameters derived from wrist- and waist-worn ActiGraph GT3X accelerometers, employing placement-specific cut points, for patients undergoing PD treatment.

Methods

Participants

This was a cross-sectional study. A convenience sample of participants were recruited from a peritoneal dialysis centre throughout the year of 2023 in Shanghai, China. Eligibility criteria included: (1) age 18 years or older, (2) diagnosis of end-stage renal disease with at least six months of PD treatment, and (3) the capability to walk unassisted. Participants were excluded if a physician advised against regular physical activity. A target sample size of 30 participants was determined based on recent calibration studies [14, 15]. The study was approved by the Ethics Committee of the study hospital (SH9H-2023-T271-1), and all participants provided informed consent.

Accelerometers and procedures

ActiGraph GT3X+ (ActiGraph, Pensacola, Florida) triaxial accelerometers were utilised to assess time spent in various intensities of physical activity and sedentary behaviour. Participants were instructed to wear two devices, one on the right waist and the other on the non-dominant wrist, with both initialised to collect raw data at 30 Hz concurrently. Given the typically low-intensity physical activity of dialysis patients, a 60-second epoch was selected [16]. Participants were asked to wear the devices continuously for 24 h a day for seven consecutive days, removing them only for showering and water-based activities. A log sheet was provided to record sleep and wake times. The devices were purchased by the research team using their own funding.

Data reduction

The accelerometer data were downloaded using ActiLife v6.13.3 (ActiGraph, Pensacola, FL). Wake times were manually identified from the log sheets to delineate active periods. Since our study did not analyse sleep data, non-wear time was defined as any sequence of 60 or more consecutive minutes of zero activity counts [17]. Valid data were those meeting a minimum of three days with over eight hours of wear time [18]. To calibrate the timestamps between the two monitors, the same wear time was adopted to ensure date consistency while performing the data analysis. Data were categorised into mean daily sedentary time, light physical activity (light PA),

and moderate-to-vigorous PA (MVPA) based on vector magnitude counts. Published cut-points specific to waist- and wrist-worn placements were applied to analyse these intensities. Due to the absence of validated accelerometer thresholds for PD patients, we employed wrist-specific cut-points derived from general adult populations and waist-worn thresholds previously used in haemodialysis populations. However, these metrics require cautious interpretation given the lack of established thresholds specifically for PD patients. For wrist-worn ActiGraph, we calculated sedentary time based on a cut-point of < 2,860 counts/min. For light PA, the cut-points were set from 2,860 to 3,940 counts/min. MVPA was defined as ≥ 3,941counts/min [13]. For waist-worn ActiGraph, sedentary time was defined as < 100 counts/min. For light PA, the cut-points were set from 100 to1,951 counts/min. MVPA was defined as ≥ 1,952 counts/min [16].

Statistical analysis

Data analysis was performed using SPSS Statistics 24 (IBM Corp). Descriptive statistics were presented as mean, standardized deviations (SD), or frequencies and percentages. Independent *t*-tests and chi-square tests were performed to assess differences in demographic and clinical characteristics between subgroups of patients who met versus did not meet the World Health Organization (WHO) recommendations for physical activity [19]. Intra class coefficients (ICC) and Bland-Altman plots were used to analyse the agreement between the two methods. 95% confidence intervals (95% CIs) of the ICC (2-way random, absolute agreement, single measures) values of < 0.50 were considered poor reliability, values between 0.50 and 0.75 were taken to indicate moderate reliability, values between 0.75 and 0.90 were considered good reliability, and values between 0.90 and 1.00 were considered excellent reliability [20]. Bland-Altman plots were applied to visualise the magnitude of agreement between the two devices for sedentary time and physical activity data. In the Bland-Altman plots, differences were expressed as waist-worn data subtracted from the wrist-worn data. The mean bias, 95% limits of agreement (LoA), and 95% CIs of LoA were calculated. In addition, equivalence was examined using pairwise equivalence testing. Previous research has shown that waist-worn ActiGraph devices provide more accurate estimates of active energy expenditure during walking and household activities compared to wrist-worn devices in a lab [21]. Thus, waist-worn ActiGraph estimation was used as the gold standard in the Bland-Altman analysis. The mean ratio of sedentary or physical activity estimates between waist-worn and waist-worn GT3X was compared with the upper and lower limits of 10% equivalence zones (Hal: 0.9 < mean ratio; and Ha2: mean ratio < 1.11 [22]. If 90% confidence intervals fell entirely in within equivalence bounds, the wrist-worn GT3X estimates were considered statistically equivalent to the waist-worn GT3X values on average. Equivalence analyses were performed using the Ln transformation of the original data when data was not normally distributed. Equivalence analyses and graphical illustrations were performed using Minitab® 21.4.2. Bland-Altman plots were computed using MedCalc. There were no missing data in the dataset. All statistical tests were two-tailed with a 5% significance level.

Results

The characteristics of the participants are detailed in Table 1. A total of 31 PD patients were included in this study, with a mean age of 57.9 years. The majority of participants were females (58.1%). The mean body mass index was 24.3 kg/m^2 (SD = 3.8). Hypertensive nephropathy was identified as the major primary aetiology of end-stage renal disease among participants. When comparing subgroups of patients who met versus did not meet the WHO recommendations for physical activity based on waist-worn estimates, significant differences were observed only in mean age ($p = 0.014$). No significant differences were noted in other demographic or clinical variables.

Agreement between sedentary and physical activity parameters provided by the waist-worn and the wrist-worn actigraph GT3X

The total wear time recorded for the wrist-worn and waist-worn devices was 14.8 ± 1.6 h, 14.8 ± 1.7 h, respectively. The activity metrics are presented in Table 2. The agreement between the wrist- and waist-worn devices for sedentary time classification was excellent, with an ICC of 0.98 (Table 2). The Bland-Altman plot revealed a mean bias of − 33 min per day for sedentary behaviour, with 95% limits of agreement ranging from − 162 to 95 min per day (Fig. 1a), which falls within the predefined equivalence zone (waist-worn light PA/wrist-worn sedentary time ratio = 1.0; 90% CI: 0.9, 1.0) (Fig. 2a).

For light PA, the agreement was good, with an ICC of 0.76 (Table 2). However, equivalence testing indicated that the waist-worn device overestimated light PA significantly (ratio 1.4; 90% CI: 1.2, 1.6), exceeding the equivalence zone for waist-worn light PA/wrist-worn light PA (0.9, 1.1) (Fig. 2b). The Bland-Altman plot confirmed this overestimation, with a mean difference of 45.0 min per day (Fig. 1b).

The agreement for MVPA was poor, with an ICC of 0.35. The Bland-Altman plot showed that the wrist-worn device estimated an average of 3.2 units higher MVPA than the waist-worn device (Fig. 1c). Equivalence testing corroborated this underestimation by the waist-worn device compared to the wrist-worn estimates (ratio 0.5; 90% CI: 0.3, 0.8) (Fig. 2c).

Table 1 Participant characteristics

Demographics	All subjects (*n* = 31)	Subjects reaching PA recommendations (*n* = 9)	Subjects not reaching PA recommendations (*n* = 22)	*P*
	Mean (SD)/*n* (%)			
Age, years	57.9 ± 12.4	49.6 ± 10.4	61.4 ± 11.7	0.014
Sex				
Female	18 (58.1)	5 (55.6)	13 (59.1)	0.857
Educational level				0.926
Primary below	8 (25.8)	2 (22.2)	6 (27.3)	
Secondary	19 (61.3)	6 (66.7)	13 (59.1)	
High education	4 (12.9)	1 (11.1)	3 (13.6)	
Employment				0.586
Employed	4 (12.9)	2 (22.2)	2 (9.1)	
Retired	24 (77.4)	6 (66.7)	18 (81.8)	
Unemployed	3 (9.7)	1 (11.1)	2 (9.1)	
Relationship status				0.203
Married	29 (93.5)	8 (88.9)	21 (95.5)	
Divorced/separated	1 (3.2)	1 (11.1)	0 (0)	
Widowed	1 (3.2)	0 (0)	1 (4.5)	
Etiology of end-stage renal disease				0.532
Chronic glomerulonephritis	6 (19.4)	2 (22.2)	4 (18.2)	
Diabetic nephropathy	6 (19.4)	2 (22.2)	4 (18.2)	
Hypertensive nephropathy	16 (51.6)	5 (55.6)	11 (50.0)	
Other	3 (9.7)	0 (0)	3 (13.6)	
Comorbidities				
Hypertension	7 (22.6)	3 (33.3)	4 (19.0)	0.658
Diabetes mellitus	5 (16.1)	1 (11.1)	4 (18.2)	1.000
Cardiovascular diseases	1 (3.2)	0 (0)	1 (4.5)	1.000
PD vintage, years	4.7 ± 2.4 (2–11)	4.2 ± 2.2	4.9 ± 2.5	0.481
PD modality				
CAPD	29 (93.5)	9 (100)	20 (90.1)	0.350
APD	2 (6.5)	0 (0)	2 (9.1)	
Dialysis dose, L	8000 ± 516.4	8000 ± 0	8000 ± 617.2	1.000
Total Kt/V	2.0 ± 0.6	1.8 ± 0.5	2.1 ± 0.7	0.303
Body mass index, kg/m^2	24.3 ± 3.8	22.9 ± 3.3	24.9 ± 3.9	0.193
24-h urine output, ml	514.5 ± 494.2	394.4 ± 346.8	563.6 ± 542.5	0.396
Creatinine, μmol/L	1051.1 ± 365.2	1152.8 ± 360.5	944.5 ± 358.8	0.156
Hemoglobin, g/L	107.8 ± 14.6	115.7 ± 21.2	110.7 ± 17.4	0.501
Serum albumin, g/L	33.4 ± 4.1	33.3 ± 4.6	33.4 ± 4.6	0.983
Serum phosphorus, mmol/L	1.8 ± 0.6	1.7 ± 0.6	1.8 ± 0.6	0.749
Total cholesterol, mmol/L	4.6 ± 1.4	4.8 ± 1.6	4.5 ± 1.4	0.582
Total triglycerides, mmol/L	2.2 ± 1.1	2.7 ± 1.8	2.0 ± 0.7	0.277
Lean tissue mass, kg/m^2	34.4 ± 11.2	35.9 ± 8.6	33.8 ± 12.2	0.644
Fat tissue mass, kg/m^2	19.9 ± 6.9	17.2 ± 4.3	21.0 ± 7.5	0.162

Abbreviations: PA = physical activity; PD = peritoneal dialysis; CAPD = continuous ambulatory PD; APD = automated PD

Discussion

The ActiGraph GT3X device is increasingly utilised for the assessment of physical activity and sedentary behaviour, offering the flexibility to be worn at the waist or wrist. The wrist-worn configuration has been shown to enhance participant compliance, making it a preferred method for numerous researchers [23]. The use of different placement sites for assessing free-living physical activity necessitates a clear understanding of the concordance between accelerometer measurements of sedentary behaviour and physical activity, particularly when utilising specific data reduction methodologies for these positions. This study is among the pioneering efforts to compare physical activity and sedentary time measured by wrist- and waist-worn ActiGraph GT3X devices, employing placement-specific cut-points under

Table 2 Agreement between sedentary and PA parameters provided by the waist-worn and the wrist-worn activity trackers

ActiGraph measure	Wrist-worn mean (SD)	Waist-worn mean (SD)	ICC	95% CI
Sedentary, min/day	746.7 ± 117.6	713.2 ± 118.8	0.984	0.967, 0.992
Light PA, min/day	118.5 ± 61.8	163.4 ± 72.9	0.761	0.562, 0.877
MVPA, min/day	21.3 ± 22.8	10.9 ± 16.6	0.352	0.002, 0.624

PA: physical activity; MVPA: moderate-to-vigorous physical activity; VM: vertical magnitude; ICC: intra class correlation (two-way random model, absolute agreement)

free-living conditions for PD patients. The findings indicate substantial agreement between the wrist- and waist-worn devices for sedentary time estimation, with an ICC of 0.98, falling within the equivalence zone. For light PA, the ICC suggested good agreement, yet it did not meet the equivalence criteria; in contrast, the agreement for MVPA was poor.

The generation of comparable sedentary outcomes from both device placements, using specific cut-points, could facilitate research and clinical comparisons within the PD population. A recent study has indicated that prolonged daily sedentary time, exceeding 12 h, coupled with less than 22 min of MVPA, is associated with an elevated mortality risk (HR 1.38, 95% CI 1.10 to 1.74) [24]. It is noteworthy that the accumulation of time within the sedentary cut-point categories, rather than the acceleration values themselves, is the critical factor. Previous studies have reported that accelerometers are unable to differentiate postures using acceleration alone [25, 26]. Since quantities of time accumulated within sedentary cut points are mostly evaluated outcome values, the high correspondence between sedentary time estimated from wrist- and waist-worn ActiGraph GT3X with placement-specific cut-points could be deemed clinically significant. The sedentary time derived from these devices should be interpreted as a spectrum of inactivity, rather than merely time spent sitting or lying down [27]. Hence, it is better for researchers to define sedentary time estimated from Actigraph GT3X whether worn on waist or wrist with placement specific cut-points as being inactive, namely not meeting specified levels of physical activity (e.g., typically ≤ 1.5 metabolic equivalence). Our results indicate that the time spent in sedentary obtained by waist- and wrist-worn ActiGraph GT3X can be considered comparable. Being the wrist-worn accelerometers more comfortable than waist-worn ones, it seems logical to conclude that this could be the recommended option for measuring sedentary behavior under free-living condition for PD patients.

Physical activity assessment relies on accelerometer-derived time-in-intensity metrics, calculated using predefined thresholds for activity levels. Despite the

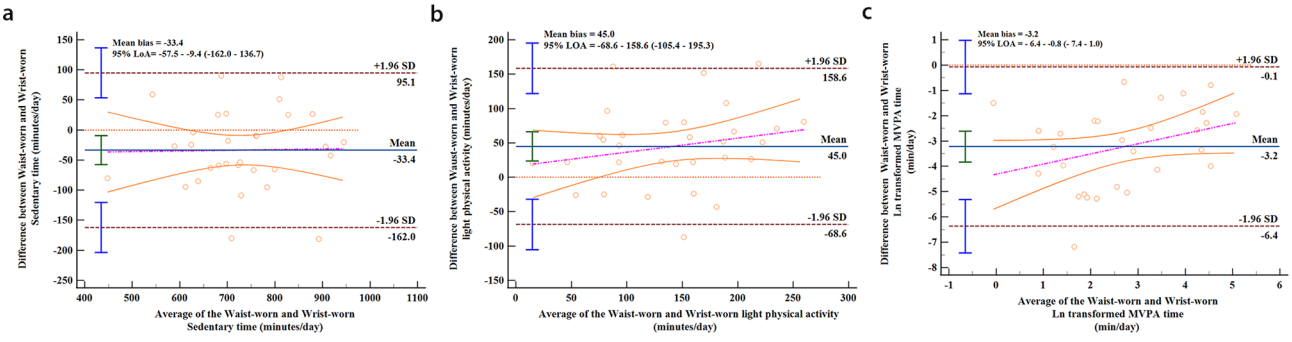

Fig. 1 **a** The Bland-Altman plot for the sedentary time provided by waist-worn and wrist-worn activity trackers. **b** The Bland-Altman plot for the light PA time provided by waist-worn and wrist-worn activity trackers. **c** The Bland-Altman plot for the MVPA provided by waist-worn and wrist-worn activity trackers. [Ln transformation]

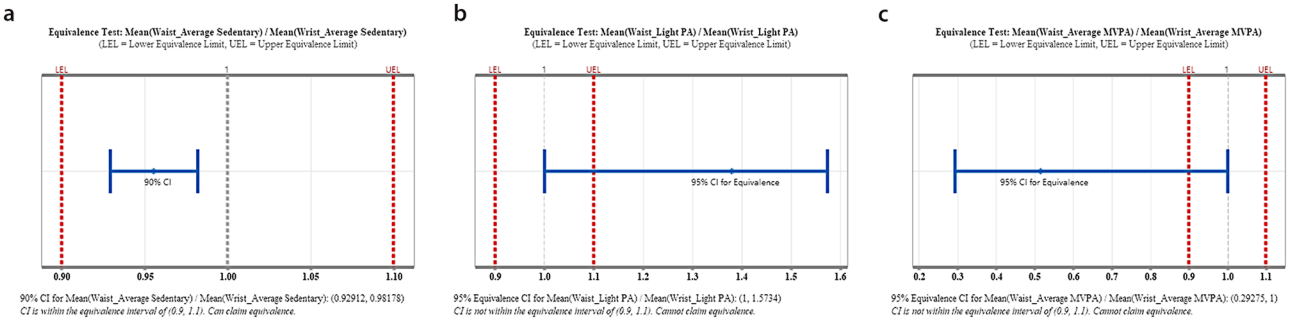

Fig. 2 **a** The Equivalence test for the sedentary time provided by waist-worn and wrist-worn activity trackers **b** The Equivalence test for the light PA time provided by waist-worn and wrist-worn activity trackers **c** The Equivalence test for the MVPA time provided by waist-worn and wrist-worn activity trackers

application of placement-specific cut-points in this study, variations in the estimation of physical activity intensities were observed between wrist- and waist-worn ActiGraph GT3X devices. Although reliability for light PA was good, equivalence was not achieved. Mandigout et al. [28] reported that the wrist-worn estimation tends to overestimation low-speed activities, and underestimate high-speed activities. However, our findings indicated that wrist-worn estimates were conservative for light intensities, whereas higher MVPA estimates were observed for the wrist-worn device. This suggests that the wrist-worn estimates are not consistently overestimating physical activity levels. This inconsistency in wrist-worn estimates may stem from differences in sensitivity thresholds between wrist- and waist-worn devices for various activity intensities. The agreement for MVPA was poor, with an ICC of 0.35. The poor classification of MVPA for wrist-worn estimations is consistent with previous findings, in which discrimination of MVPA behaviour for the wrist-worn device was shown to be poor for a sample of healthy older adults in a laboratory setting [29]. This is most likely a function of high variability and limited time spent in MVPA in PD patient in this study. Another reason for those differences may be the different movements between the wrist and the waist during the same activity as indicated in the previous studies [30, 31]. Variations in sensor sensitivity and motion detection capabilities across placement sites may also play a role. Specifically, wrist-worn devices exhibit higher responsiveness to upper limb movements, potentially inflating MVPA estimates compared to waist-mounted counterparts. Although statistically significant, the clinical relevance of these discrepancies remains uncertain, necessitating further investigation into their impact on therapeutic decision-making. Caution should be exercised when comparing habitual physical activity levels across studies using different ActiGraph GT3X placements for PD patients, given the discrepancies observed in this study's MVPA metrics, even with the application of placement-specific cut-points.

Several limitations must be acknowledged when interpreting the findings of this study. First, the absence of a definitive benchmark for assessing sedentary behaviours and physical activity in naturalistic settings precludes a definitive conclusion on the most accurate device positioning. Second, the cross-sectional design of the study precludes the establishment of causal relationships, as it only captures data at a single point in time. Future longitudinal research is needed to explore the consistency of wrist-worn accelerometer estimates over time. Third, the modest sample size ($n = 31$), derived from convenience sampling, may limit generalisability to the broader PD patient population and reduce power to detect clinically meaningful differences. Larger studies are needed to validate these findings. Finally, the lack of established gold-standard thresholds for either the waist-worn or wrist-worn GT3X specifically tailored for this patient group introduces uncertainty in interpreting physical activity levels and adherence to guidelines.

Conclusions

This study suggests that the mean duration of sedentary behaviour, as recorded by waist- and wrist-worn ActiGraph GT3X devices, can be considered equivalent when utilising cut-points specific to the measurement site. However, significant discrepancies in physical activity metrics were observed. Uniformity in device wear location is essential for intra-study assessments of physical activity to reduce inter-subject variability. Given the importance of light PA and MVPA for individuals undergoing PD treatment, further research is warranted to elucidate the reasons behind the activity type-specific discrepancies associated with different accelerometer wear locations.

Abbreviations

ICC	Intraclass correlation coefficients
CI	Confidence intervals
PD	Peritoneal dialysis
PA	Physical activity
MVPA	Moderate-to-vigorous PA
SD	Standardized deviations
LoA	Limits of agreement

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Author contributions

XJT designed the study, LZ, JJL, FW collected the research data, MZC, CH, LZ, JJL, FW, XJT analyzed research data and completed the interpretation, MZC wrote the main manuscript, and All authors reviewed the manuscript.

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Data availability

The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The Ethics Committee of Shanghai Ninth People's Hospital, Shanghai Jiao Tong University School of Medicine approved the study protocol (SH9H-2023-T271-1). The study followed accepted ethical standards, as outlined in the Declaration of Helsinki. The purpose of the study was explained to the participants, and written informed consent was obtained.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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