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Understanding psychophysiological responses to walking in urban settings in Asia and Africa

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ABSTRACT

Global transition into healthy urban living requires active engagement by planners to understand the physical and social dimensions that underpin healthy living in urban settings. Much of the current research into the health and wellbeing benefits that can be afforded by smart planning has taken place in the Global North, with little focused attention on other parts of the world. Given the current rapid urbanization in both sub-Saharan Africa and South-East Asia, further research is needed to understand how urbanisation is impacting these populations in order to understand what public health measures can be implemented.

Our research sought to understand the psychophysiological responses of participants in Nakuru (Kenya) and Udon Thani (Thailand) when walking in urban settings within their given city. Mood measures were taken pre- and post-walk, to understand subjective psychological responses to the urban settings. Heart rate variability was measured using a smart watch to understand physiological (stress) responses throughout walks in the urban settings.

Our results show beneficial effects of nature within urban settings on heart rate variability, suggesting lower stress responses in these areas. The subjective responses did not show the expected improvements in mood across both locations as a result of walking generally, which we discuss in relation to geographical and/or potential social differences in these locations compared against studies that have been conducted largely in the Global North. The results of this study are useful in understanding the role of urban planning for improved public health in both African and Asian settings.

1. Introduction

With the global transition to urban living, cities need to become sustainable, which increasingly includes concepts of wellbeing and quality of life alongside environmental, infrastructure and economic considerations (Leach et al. 2014). Rapidly developing cities represent unique challenges and opportunities for sustainable development. However, unplanned growth often outpaces infrastructure provision and occurs at the expense of a city's ecological foundations, undermining residents' wellbeing and the city's sustainability (McPhearson et al. 2016). Addressing this requires moving beyond meeting basic needs and towards enabling residents to achieve their aspirations, including consideration of the social aspects of city living, such as people's satisfaction, experiences and perceptions of their everyday environments (Corburn, 2017). This requires that planners have greater understanding of a cross-section of residents needs and wants (Nikulina et al. 2019; Soja, 2010).

The current rapid urbanization in sub-Saharan Africa poses many serious challenges for African cities, including growing pressure on natural resources, increasing environmental and climate change-related vulnerabilities, urban poverty and the proliferation of informal settlements (UN-Habitat 2014; African Development Bank 2012). These challenges are exacerbated by weak urban planning, and inadequate urban governance (UNECA 2014; UN-Habitat 2014). Similarly, South-East Asia and the Pacific is already 60% urban while South Asia is at 34% (United Nations: Department of Economic and Social Affairs Population Division. 2019), but this number is growing, and over 130 million South Asian live in informal settlements (Ellis & Roberts, 2016), facing the attendant problems of inadequate sanitation and housing, and exposure to poor air quality.

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Concurrent to the trends towards urbanization is the public health issue of ensuring that populations are able to maintain health and wellbeing within these spaces. An example of this would be to engage in walking, with both US and UK guidelines suggesting that adults should aim to undertake at least 150 min of moderate intensity exercise a week (CDC, 2020; NHS, 2022), based on the World Health Organisation global recommendations (World Health Organisation, 2022). There is growing evidence regarding the importance of nature immersion for health (Tzoulas et al. 2007) including both mental wellbeing (Pasanen et al. 2014) and physical health (Bertram & Rehdanz, 2015). There is a large body of evidence that supports the benefits of urban green spaces – and indeed larger natural spaces – on wellbeing, including reducing stress as measured by cortisol (Ward Thompson et al. 2012, Roe et al. 2013), improving cognitive performance post-walking in green space (Berman et al., 2008, 2012), decreasing neural activity associated with depressive symptoms (Bratman et al. 2015) and impacting brain activity associated with relaxed states (Neale, Aspinall, et al. 2020). Green spaces are considered an ecosystem service that can provide vital support for the promotion and support of health and wellbeing within a given location or region (Douglas et al. 2017). While research has suggested there are benefits of nature in non-western cultures (van den Berg et al. 2018; Barros et al. 2021), much of the current literature assessing subjective and/or physiological responses to urban and natural spaces have been conducted in Global North settings, specifically Europe, Australia, USA and north-east Asia (Takano et al. 2002; Wolch et al. 2014). Our recent work attempted to compare health, sub-chronic stress and wellbeing in response to greenspace across three continents (Neale, Besa, et al., 2020), including non-Western countries (Kenya and Thailand), as a response to this, but further work is needed to build on this research. Across Asia and Africa, there is a need to understand the psychological impacts of the local built environment on urban residents in order to understand how to support city populations wellbeing and sustainability.

There is further need to understand wellbeing in built urban spaces in addition to the perceived restorative natural spaces. This is particularly important for identifying how to optimize urban living in rapidly urbanising cities, such as those in non-Western countries. Research has begun to highlight restorative built urban spaces, focusing on levels of interest or attractiveness (Karmanov & Hamel, 2008) or how removal of traffic and inclusion of historic interest (Bornioli et al. 2018) might contribute to restorative effects in these settings. Recent work looking at simulated nature walks presents a possible continuum of restoration between nature and urban settings (Brancato et al. 2022), further developing the notion of inter-category differences in nature and urban settings. Stress physiology, specifically heart rate variability (HRV), has increasingly been used as a reliable measure for assessing acute health outcomes in urban spaces (Kondo et al. 2018; Mygind et al. 2021; Twohig-Bennett & Jones, 2018). HRV represents the fluctuation in the time intervals between adjacent heartbeats where higher HRV values are associated with improved physiological health and self-regulatory capacity or resilience (Kondo et al. 2018), as well as being linked to psychological processes such as attention and emotion (Reeves et al. 2019). Fieldwork has shown benefits of walking in urban green spaces on HRV when compared to urban built/grey spaces (Hystad & Cusack, 2019; Roe et al. 2020; Song et al. 2013). There are various mechanisms suggested as the reason for this, a primary theory being Attention Restoration Theory (ART) which suggests that restorative environments (which tend to include green spaces) allow us to replenish depleted cognitive faculties (Kaplan, 1995, 2001; Kaplan & Kaplan, 1989). While there is evidence to suggest psychophysiological benefits across the lifespan of walking (Celis-Morales et al. 2017; Christian et al. 2018; Connolly et al. 2019; Raine et al. 2017), there appear to be additional health benefits occurring when walking within green spaces (Gidlow et al. 2016; Janeczko et al. 2020; Tilley et al. 2017), suggesting that promotion of physical activity within urban green spaces may have public health benefits (Macpherson et al. 2017).

Given the emerging research that shows the benefits of engaging within urban built and green spaces and wishing to understand if these benefits translate to African and Asian settings, this paper draws on the findings from two case study cities, Nakuru in Kenya, and Udon Thani in Thailand, to understand how urban spaces can impact psychophysiological outcomes. An initial scoping exercise in each city revealed differences in perceptions of relaxation and stress throughout the conurbations, which we utilize here to understand if this translates to psychophysiological outcomes (Tuhkanen et al. 2022). Our research questions are.

1. How does walking in a mixed urban environment impact subjective mood and physiological wellbeing? How do different urban typologies (such as green space) impact these primary outcomes?
2. Do sub-chronic measures of stress and wellbeing differ between geographic locations (Thailand and Kenya)? Are there any interaction effects between sub-chronic measures of stress and wellbeing between geographic locations and participant demographics?

2. Materials and methods

2.1. Participants

All participants ($n = 237$) were adults aged between 18 and 30 years. The research protocol was the same at the two study locations (Kenya and Thailand). Ethical approval for the study was provided by the University of York Department of Environment and Geography Ethics Committee (28th Feb 2019), with informed and signed consent a condition of taking part in the study. Participants (students) were recruited via convenience sampling methods through local Universities in both cities by local facilitators. Using G*Power (Faul et al. 2007), we estimated that, when conducting the regression models, to obtain a medium effect size, with a power of .8, each location would need at least 108 participants.

Nakuru, Kenya: 122 participants (58 male, 64 female) took part in this study in Nakuru, aged between 18 and 30 years (mean age = 23.76 years, $SD = 3.32$). Testing for this group took between 10th to 26th April 2019.

Udon Thani, Thailand: 115 participants (57 male, 58 female) took part in this study in Udon Thani, aged between 18 and 30 years (mean age = 24.39 years, $SD = 3.23$). Testing for this group took place in between 22nd March 2019 to 13th April 2019.

2.2. Design and procedure

This study looked to assess the impacts of walking in urban settings (including both built and green spaces) on our primary outcome measures of mood and physiological stress. The experimental design and procedure was the same for both cities, but the route content differed between study locations (as described below). Participants were recruited primarily from the local universities who were aged between 18 and 30 with no self-declared health or mobility issues. We aimed to recruit as close to a 50:50 gender split as possible in both study locations. Participants arrived at a predetermined location near the start of their assigned walking condition; participants were randomly allocated to one of the two walking directions prior to arrival. Once informed consent had been obtained, participants were fitted with a Huawei Watch 2, set to record HRV using the SWear application (Boukhechba & Barnes, 2020). Participants then completed a short survey, collecting responses to the primary and secondary outcomes; perceived stress (PSS), wellbeing (SWEMWBS) and acute mood (MACL) as well as demographic information (age, gender). Surveys were delivered in English (Kenya) and Thai (Thailand). Participants undertook their walk accompanied by a researcher as a guide and observer. At the end of the walk, participants completed a second MACL survey concluding their participation in the study. Participants were paid a small remuneration for their time.

2.3. Outcome measures

2.3.1. Primary outcome measures

1. **Mood;** measured using the short version of the University of Wales Institute of Science and Technology (UWIST) Mood Adjective Check List (MACL) which measures participants' hedonic tone, stress, and arousal (Matthews et al. 1990). The scale used requires participants to respond to 12 descriptive statements, measuring acute responses, relating to how they feel at the present moment (e.g., 'energetic' or 'happy'), which they respond to on a 4-point scale [definitely, slightly, slightly not, definitely not], with each point scored from 1 to 4. Each subcomponent (hedonic tone, stress, and arousal) is measured across four descriptors and scores for each range from 4 to 16 with higher scores indicating higher hedonic tone (positive valence), stress or arousal. Environmental Psychology research has successfully used the UWIST to measure changes in mood between pre- and post-activities in urban spaces (Coventry et al. 2019; Roe et al. 2020).
2. **Physiological stress;** measured by heart rate variability (HRV) obtained using the Huwei Watch 2 wearable device, worn on participants' non-dominant wrist. We used an in-house built app to collect 100HZ Photoplethysmogram (PPG) and 1/60HZ GPS data (Boukhechba & Barnes, 2020). Increase in blood pressure, which can be unobtrusively captured via PPG, is also a well-documented indicator of stress (Arza et al. 2019; Kok et al. 1995). The rise time of the PPG signal corresponds to speed at which the blood pressure spikes; higher rise time indicates lower stress (Sahni, 2012). Lower levels of HRV are widely regarded as a robust clinical marker of health deterioration and physical and mental stress (Dekker et al. 2000; Taelman et al. 2009).

2.3.2. Secondary outcome measures

We further added two subjective measures in order to understand sub-chronic mood and wellbeing prior to the walking session. We looked to use these secondary measures to understand any differences in sub-chronic wellbeing between participants in each of our cities of interest.

1. **Sub-chronic stress;** measured by the Perceived Stress Scale (PSS) (Cohen et al. 1983) evaluates subjective levels of sub-chronic stress over the previous 30 days. Survey questions were designed to measure how unpredictable, uncontrollable, or overloaded respondents find their lives (Cohen et al. 2014) and has been used successfully in European, African and Asian contexts (Neale, Besa, et al. 2020). Participants respond to 10 questions (e.g. '*How often have you felt nervous and stressed?*'), indicating on a 5-point scale [never, almost never, sometimes, fairly often, very often] how often these statements applied to them over the previous 30 days. Each response point is scored from 0 to 4 and summed to create an overall score (ranging from 0 to 40) where higher scores indicate higher levels of subjective, sub-chronic stress.
2. **Wellbeing;** measured by the Short Warwick Edinburgh Mental Wellbeing Scale (SWEMWBS) that assesses subjective wellbeing through *seven questions rated on a 5*-point Likert scale which have been validated for construct validity (Stewart-Brown et al., 2009). The scale has been used successfully used in Europe (Koushede et al., 2019), Asia and Africa (Neale, Besa, et al., 2020). Participants respond to 7 descriptive statements (e.g. '*I've been dealing with problems well*'), indicating on a 5-point scale [never, rarely, sometimes, often, all the time] how often these statements applied to them over the previous 2 weeks. Each response point is scored from 1 to 5 and summed to create an overall score (ranging from 7 to 35) where higher scores indicate higher levels of subjective wellbeing.

2.4. Site selection

Two sites were chosen based on criteria including comparable population size and recent growth rates, and both sites have a mix of formal and informal development. Both cities also exhibit a range of environmental concerns that they are partly trying to address through urban greening (green infrastructure and nature based solutions). This was part of a larger interdisciplinary study on the impacts of urban forms on health and wellbeing in secondary cities in Low- and Middle-Income Countries (LMICs) of which this research is one component. The cities chosen (shown in Fig. 1) are Nakuru, Kenya and Udon Thani, Thailand. Both are rapidly urbanising secondary cities in their respective countries. A series of images from both the Nakuru and Udon Thani walking routes can be found in the Supplementary Material.

1. **Nakuru** is the fourth-largest city in Kenya after Nairobi, Mombasa and Kisumu, 160 km North West of Nairobi, with a population of over 570,000 people. It has a mixture of natural and built environments, including informal and unplanned settlements and green and blue spaces. Rapid growth in Nakuru, estimated at 7% per annum (Ehrensperger & Mbuguah, 2004), is putting development pressure on public realm, green and blue spaces. This population growth is expected to put pressure on existing resources and amenities and exacerbate issues of water shortage, poor sanitation, waste management and unplanned informal settlements, unless adequately planned for. Nakuru has a Mediterranean climate remaining temperate throughout the year with no annual dry season.

We selected a walking route in the central business district (CBD) that included a green park, bus terminal and market areas. The route was selected to include locations described as stressful (bus terminal) and relaxing (park) in a scoping exercise (Tuhkanen et al. 2022). Fig. 2 shows a map of the route. The route was 780m in total and 134m of this was green space (23% of the total route).

2. **Udon Thani** in Northeast Thailand is a small city of 130,000 residents facing rapid development due to its strategic location near the Laos border. Udon Thani is exposed to both flooding and drought, and is heavily reliant on one reservoir for its water supply. While the city has engaged in international projects to build capacity relating to water management and climate resilience, the Udon 2029 process is home-grown through a collaboration of city stakeholders, ranging from the municipality, academia, local businesses and local communities. The city has a tropical savanna climate with warm dry winters (October–March) followed by a six-month monsoon season (April–September).

We selected a walking route was on the eastern periphery of the CBD that included a green park, railway and market areas. These locations again included a mixture of stressful and relaxing spaces according to the scoping exercise (Tuhkanen et al., 2022). Fig. 3 shows a map of the route. The route was 1180m in total and 273m of this was in green space, While the Udon Thani route is longer than the Nakuru route, there is a comparable amount of green space in both walks.

2.5. Statistical analysis

2.5.1. Primary outcome analyses: Within-location

Our first analysis focused on each location specifically, understanding the impact of the walking routes on the primary outcome measures; acute-mood and HRV.

2.5.2. Mood analyses

To understand changes in mood outcomes (MACL) as a response to walking, we ran paired t-tests between our pre- and post-walk MACL outcomes to show any change between these, irrespective of the route

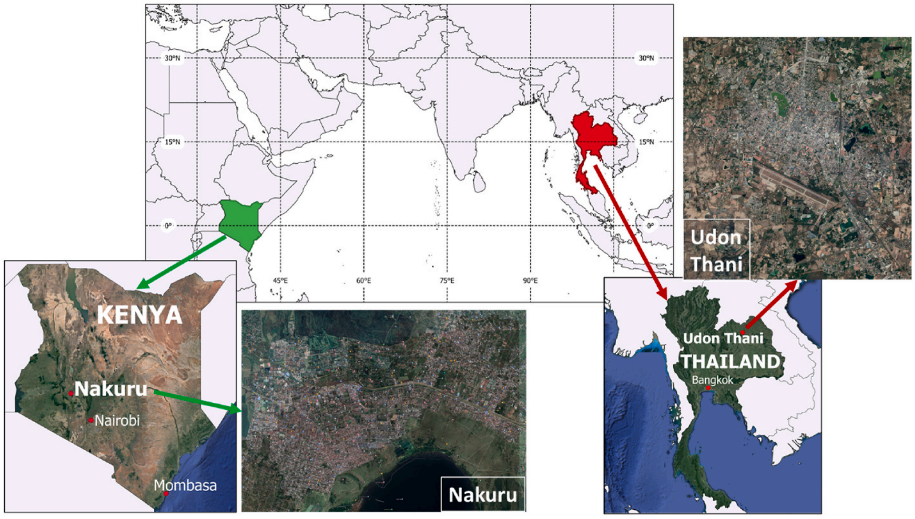

Fig. 1. Research site locations in Kenya (Nakuru) and Thailand (Udon Thani).

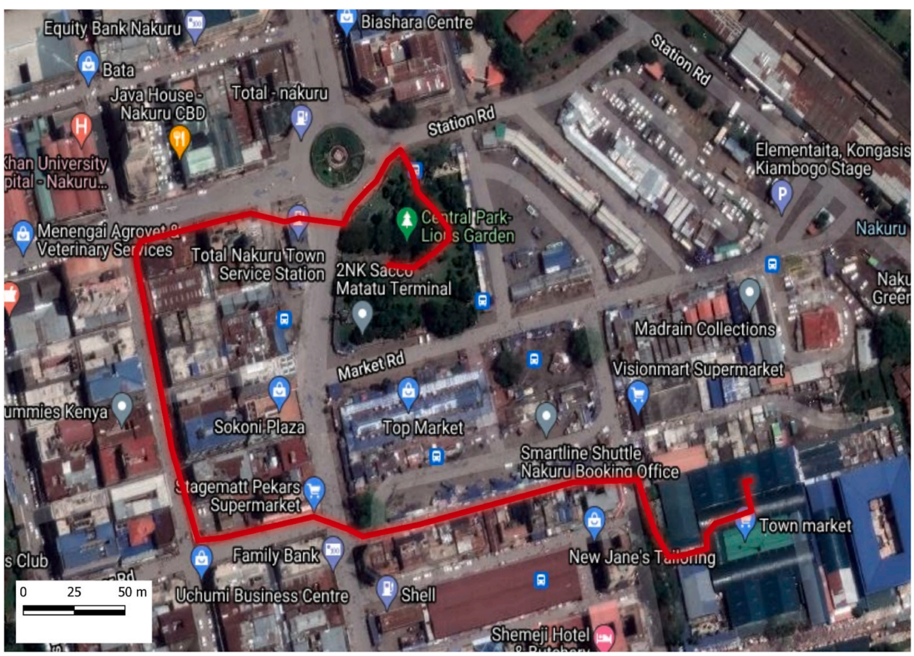

Fig. 2. Nakuru walking route map. Participants walked the indicated route starting either in the Town Market or in the Central Park area.

order walked. We then ran three linear regressions on each of the post-walk MACL mood outcomes. For each dependent variable (hedonic tone, acute stress and arousal), we used route order, gender (both dummy coded as 1 and -1 for the purposes of the regression), matching pre-walk MACL mood outcome and the secondary outcome measures, PSS and SWEMWBS as predictors.

2.5.3. *HRV analyses*

As HRV data consisted of multiple observations per participant, a multilevel random coefficient modelling approach with a random intercept for each participant (n = 237) was used, as per our previous work (Roe et al., 2020). The model was fit using full information maximum likelihood estimation to study the effect of route order on HRV. The model examines the relationship between HRV as characterized by the Root Mean Square of Successive Differences between normal heartbeats (RMSSD) and sections of the walk as they relate to each other. To control for HRV variation over time, the time passing from the start of the walk was included as a random slope in the model.

2.5.4. *Secondary outcome analyses: Between-locations*

To understand differences between locations, as measured by the secondary outcome measures, we ran independent t-tests on the PSS and SWEMWBS outcomes, using study location (Nakuru and Udon Thani) as the condition variable. Effect sizes for each comparison were calculated using Cohen's d (Cohen, 1988, 2013), using mean difference divided by pooled standard deviation for each condition. To further understand any possible interaction effects between study location and gender, we ran a linear regression on both the PSS and SWEMWBS outcomes, using location, gender and the location*gender interaction as predictors.

Fig. 3. Udon Thani walking route map. Participants walked the indicated route starting either in the urban part of the city or in the Nong Bua Public Park area.

3. Results

3.1. Study demographics

We present the overall study demographics for the two locations below, in Table 1.

3.2. Primary outcome measure results: Nakuru

3.2.1. Mood results

We first looked at differences between pre- and post-walk MACL outcomes, irrespective of the route order and other independent variables. We found no statistically significant difference between pre- and post-walk levels of hedonic tone ($t(121) = 0.76$, $p = .45$, 95% CI [-0.31 0.71], stress ($t(121) = 1.38$, $p = .17$, 95% CI [-0.21 1.16] or arousal ($t(121) = 0.66$, $p = .65$, 95% CI [-0.42 0.66].

A linear regression, using route order, gender, matching pre-walk MACL outcome, PSS and SWEMWBS as predictors, was run on each of the three MACL mood outcomes (hedonic tone, stress and arousal). Tabulated results can be found in the Supplementary Materials. For hedonic tone, the model was statistically significant ($F(5, 109) = 15.33$, $p < .001$) with a small to medium amount of variance explained by the model ($R^2 = 0.41$). The regression model showed that pre-walk hedonic tone levels were a statistically significant predictor of post-walk hedonic tone (B = 0.54, $p < .001$, 95% CI [0.40, 0.69]), with the Beta coefficient suggesting that the higher hedonic tone is pre-walk, the higher it will be post-walk. Neither SWEMWBS (B = 0.04, $p = .60$, 95% CI [-0.10, 0.17]) or route order (B = 0.33, $p = .16$, 95% CI [-0.13, 0.78]) were statistically significant predictors of hedonic tone post walk. Our model shows that both PSS score (B = 0.12, $p = .02$, 95% CI [0.02, 0.23]) and gender (B = −0.5, $p = .04$, 95% CI [-0.97, −0.03]) were statistically significant predictors of hedonic tone. For PSS, the Beta coefficient suggests higher perceived sub-chronic stress pre-walk predicts higher hedonic tone post walk. The Beta coefficient for gender suggest that post-walk hedonic tone is higher in female participants than male.

For acute stress, the model was statistically significant ($F(5, 109) = 9.52$, $p < .001$) with a small to medium amount of variance explained by the model ($R^2 = 0.30$). The regression model showed that pre-walk acute stress levels were a statistically significant predictor of post-walk acute stress (B = 0.47, $p < .001$, 95% CI [0.29, 0.64]), with the Beta coefficient suggesting that post-walk acute stress increases relative to higher pre-walk acute stress. Sub-chronic stress, as measured by the PSS, was also a statistically significant predictor of acute, post-walk stress (B = 0.14, $p = .05$, 95% CI [0.002, 0.27), with Beta coefficient suggesting that sub-chronic stress contributes to post-walk acute stress, with higher sub-chronic stress predicting acute-stress post-walk. SWEMWBS (B = 0.01, $p = .89$, 95% CI [0.29, 0.64]), route order (B = −0.1, $p = .73$, 95% CI [-0.65, 0.46]) or gender (B = −0.13, $p = .66$, 95% CI [-0.69, 0.44]) were not statistically significant predictors of post-walk acute stress.

For arousal, the model was significant ($F(5, 109) = 11.89$, $p < .001$) with a small to medium amount of variance explained by the model ($R^2 = 0.35$). The regression model showed that pre-walk arousal levels were a statistically significant predictor of post-walk arousal (B = 0.49, $p < .001$, 95% CI [0.33, 0.65]), with the Beta coefficient suggesting that post-walk arousal is higher when pre-walk arousal is high. PSS scores pre-walk were a statistically significant predictor of post-walk arousal (B = 0.12, $p = .04$, 95% CI [0.01, 0.23]), with the Beta coefficient indicating higher perceived stress pre-walk predicts higher subjective arousal post-walk (as shown in the hedonic tone model). SWEMWBS (B = 0.07, $p = .35$, 95% CI [-0.07, 0.21]), route order (B = 0.42, $p = .09$, 95% CI [-0.07, 0.91]) or gender (B = −0.36, $p = .15$, 95% CI [-0.86, 0.14]) were not statistically significant predictors of post-walk arousal.

Table 1
Study Demographics by location.

	Nakuru	Udon Thani
N	122	115
Gender	58 male, 64 female	57 male, 58 female
Age	*M* = 23.76 years, SD = 3.32	*M* = 24.39 years, SD = 3.23

3.2.2. HRV results

The random effects model compared HRV outcomes between walking sections, as shown in Table 2, below. The statistically significant differences in the coefficients between the green park and the bus terminal, unmarked crossing A, busy bus terminal, unmarked crossing B and mini bus market all indicate higher HRV values in the green park relative to the other locations. This same effect was seen in the (3) unmarked crossing A when compared to the busy bus terminal, unmarked

Table 2
Random effects model coefficients comparing differences in HRV between walking sections in Nakuru. Bold coefficients indicate statistically significant difference (reference is the horizontal setting).

	1: Green-Park (Start/End)	2: Busy - Bus Terminal (Start/End)	3: Unmarked Crossing A	4: Busy Bus Terminal	5: Unmarked Crossing B	6: Minibus Market
2: Bus Terminal (Start/End)	**−3.55*** **					
3:Unmarked Crossing A	**−1.59*** **	**1.95***				
4: Busy Bus Terminal	**−2.96*** **	0.59	**−1.37***			
5:Unmarked Crossing B	**−3.03*** **	0.52	**−1.44*** **	−0.07		
6: Mini Bus Market	**−2.66*** **	0.89	**−1.07***	0.30	0.37	
7: Town Market	0.04	**3.59*** **	**1.63***	**3.00*** **	**3.07*** **	**2.70*** **

*$p < .05$, ***$p < .001$.

crossing B and minibus market. The busy bus terminal showed lower HRV when compared to the unmarked crossing A and town market.

3.3. Primary outcome measure results: Udon Thani

3.3.1. Mood results

We first looked at differences between pre- and post-walk MACL outcomes, irrespective of the route order and other independent variables. We found a significant effect of walking on hedonic tone (t(114) = 2.71, p = .008, 95% CI [0.22 1.42]. We found no statistically significant difference between pre- and post-walk levels of stress (t(114) = 0.35, p = .73, 95% CI [-0.53 0.76] or arousal (t(114) = 1.92, p = .06, 95% CI [-0.02 1.34].

A linear regression, using route order, gender, matching pre-walk MACL outcome, PSS and SWEMWBS as predictors, was run on each of the three MACL mood outcomes (hedonic tone, stress and arousal). Tabulated results can be found in the Supplementary Materials. For hedonic tone, the model was statistically significant (F(5, 109) = 12.81, $p < .001$) with a small to medium amount of variance explained by the model ($R^2 = 0.37$). The regression model showed that pre-walk hedonic tone levels were a statistically significant predictor of post-walk hedonic tone (B = 0.60, $p < .001$, 95% CI [0.44, 0.77]), with the Beta coefficient suggesting that hedonic tone is higher post-walk relative to pre-walk levels. Sub-chronic stress, as measured by the PSS, was also a statistically significant predictor of acute, post-walk hedonic tone (B = −0.18, p = .03, 95% CI [-0.35, −0.02]), with the Beta coefficient showing lower sub-chronic stress significantly predicts positive acute hedonic tone post-walk. There was also a marginal statistically significant effect of route order on post-walk hedonic tone outcomes (B = −0.6, p = .051, 95% CI [-0.004, 2.41]), with the Beta coefficient suggesting that participants who started their walk in the park and finished in the market space displayed higher hedonic tone post-walk. Neither gender (B = −0.21, p = .5, 95% CI [-0.79, 1.62]) nor SWEMWBS (B = 0.06, p = .42, 95% CI [-0.08, 0.19]) were statistically significant predictors of hedonic tone post walk.

For acute stress, the model was significant (F(5, 109) = 6.41, $p < .001$) with a small amount of variance explained by the model (R^2 = 0.23). The regression model showed that pre-walk acute stress levels were a statistically significant predictor of post-walk acute stress (B = 0.40, $p < .001$, 95% CI [0.22, 0.57]), with the Beta coefficient suggesting that stress increases post-walk relative to pre-walk levels. Route order (B = 0.60, p = .33, 95% CI [-0.62, 1.82]), gender (B = 0.22, p = .73, 95% CI [−1.00, 1.43]), PSS (B = 0.16, p = .06, 95% CI [-0.004, 0.33]) or SWEMWBS (B = −0.13, p = .07, 95% CI [-0.26, 0.01]) were not statistically significant predictors of post-walk stress.

For arousal, the model was significant (F(5, 108) = 4.69, p = .002) with a small amount of variance explained by the model ($R^2 = 0.15$). The regression model showed that pre-walk measures of both PSS (B = −0.24, p = .004, 95% CI [-0.41, −0.08]) and SWEMWBS (B = 0.18, p = .008, 95% CI [0.05, 0.32]) were statistically significant predictors of post-walk arousal, with the Beta coefficients showing lower sub-chronic stress and higher subjective wellbeing significantly predict higher arousal post-walk. Pre-walk arousal (B = 0.17, p = .09, 95% CI [-0.02, 0.36]), gender (B = −0.33, p = .58, 95% CI [-0.85, 1.51]) and route order (B = 0.04, p = .95, 95% CI [−1.14, 1.21]) were not statistically significant predictors of post-walk arousal.

3.3.2. HRV results

The random effects model compared HRV outcomes between walking sections, as shown in Table 3, below. The results show higher HRV in the park when compared to the market, road crossing, green/grey transition and railway crossing. This result was also seen in the market area in comparison to all but the park condition.

4. Between location differences

We looked to assess differences in perceived stress and wellbeing between Nakuru and Udon Thani in order to understand our study population. We ran independent t-tests, using location as the condition variable; Levene's was statistically significant for the PSS outcome (p = .003), so we report adjusted degrees of freedom. Levene's was non-significant (p = .08) for the SWEMWBS, so sphericity is assumed. We found statistically significant differences, and large effect sizes, between locations for both PSS (t(213.95) = 16.23, $p < .001$, d = 2.13, 95% CI [7.58, 9.66]) and SWEMWBS scores (t(232) = 7.39, $p < .001$, d = 0.97, 95% CI [2.67, 4.60]). When we explored the means for the PSS, we see stress levels are higher in Nakuru (M = 27.69, SD = 4.62) compared to Udon Thani (M = 19.07, SD = 3.37). For the SWEMWBS, the mean wellbeing is higher in Nakuru (M = 27.02, SD = 3.42) compared to Udon Thani (M = 23.38, SD = 4.09). These results are presented in Fig. 4, below.

We ran a linear regression using location, gender and the location*gender interaction as predictors for each of the SWEMWBS and PSS outcomes to understand and effects of these variables. For the SWEMWBS, the model was significant (F(3, 230) = 19.00, $p < .001$), explaining a small amount of variance (R^2 = 0.20). The coefficients confirm the statistically significant difference in SWEMWBS scores between locations (B = 1.81, $p < .001$, 95% CI [1.33, 2.29]), but show no significant effect of either gender (B = −0.37, p = .13, 95% CI [-0.86, 0.11]) or the location*gender interaction (B = −0.05, p = .85, 95% CI [-0.53, 0.44]). Fig. 5 shows the difference between location and no interaction between these variables.

For the PSS response, the overall model was also significant (F(3, 229) = 92.25, $p < .001$), with a medium amount of variance explained by the model ($R^2 = 0.55$). As with the SWEMWBS model, we confirm the difference in PSS scores by location (B = 4.32, $p < .001$, 95% CI [3.80, 4.84]). While there was no direct effect of gender on PSS across the cohort (B = 0.27, p = .31, 95% CI [-0.25, 0.79]), we see a statistically significant interaction effect (B = 0.65, p = .01, 95% CI [0.13, 1.17]). This interaction effect suggests that PSS scores are higher in females in Udon Thani than males, but lower in Nakuru when compared to males, as displayed in Fig. 6, below.

Table 3
Random effects model coefficients comparing differences in HRV between walking sections in Udon Thani. Bold coefficients indicate statistically significant difference (reference is the horizontal setting).

	1:Park (Start/End)	2:Market (Start/End)	3: Unmarked road crossing	4: Green/Grey Transition	5: Railway Crossing
2: Market (Start/End)	**−0.98***				
3: Unmarked road crossing	**−1.92***	**−0.93***			
4: Green/Grey Transition	**−2.01***	**−1.03***	−0.10		
5: Railway Crossing	**−2.01***	**−1.03***	−0.10	0.00	
na: Other segments	**−1.70***	**−0.72***	**0.21***	**0.31***	**0.31***

*$p < .05$, ***$p < .001$.

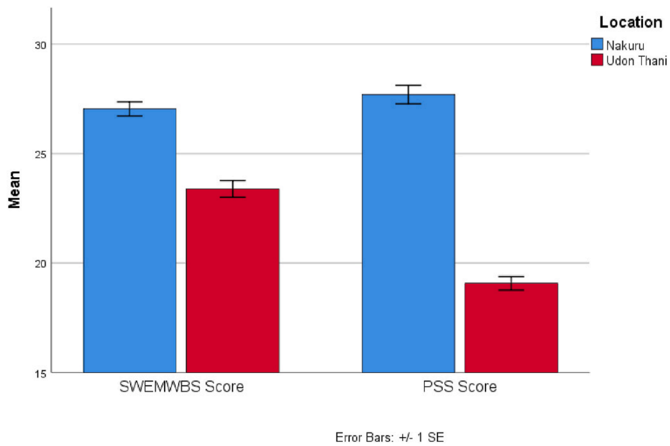

Fig. 4. Mean differences in Short Warwick-Edinburgh Mental Wellbeing Scale (SWEMWBS) and Perceived Stress Scale (PSS) outcomes by study location.

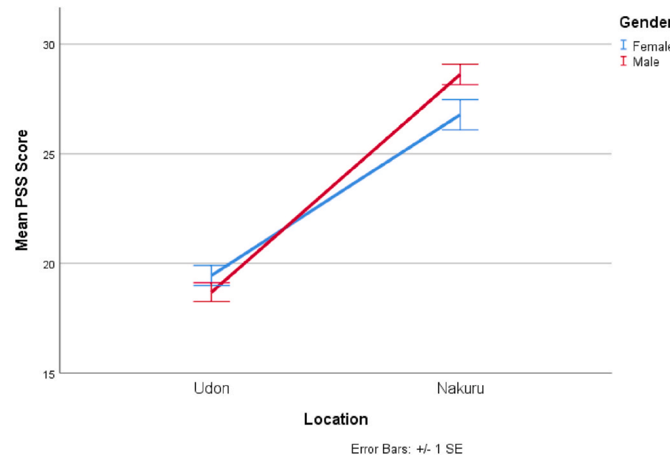

Fig. 6. Mean Perceived Stress Scale (PSS) scores at each location, displayed between gender.

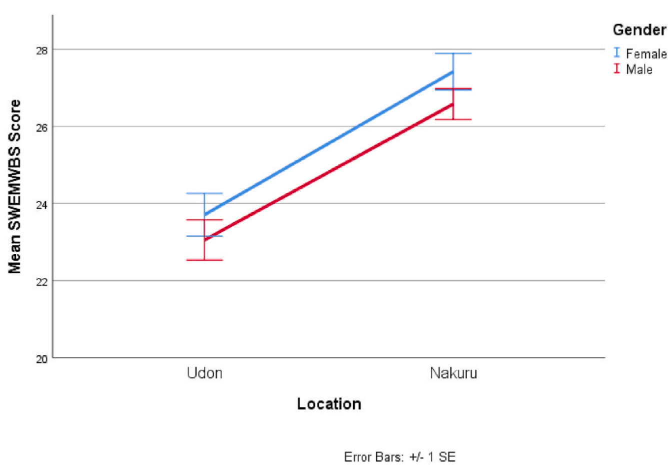

Fig. 5. Mean Short Warwick-Edinburgh Mental Wellbeing Scale (SWEMWBS) scores at each location, displayed between gender.

5. Discussion

This study shows, for the first time to the authors knowledge, consideration of psychophysiological measures in response to built urban spaces within African and Asian secondary cities, further comparing sub-chronic differences in wellbeing between the two locations.

The analysis of our primary outcome variables, addressing Research Question 1, showed some unusual findings, when compared to existing literature. In both locations, we did not see any clear benefit of walking on stress or arousal (MACL outcome measures), as expected given previous literature suggesting that walking, irrespective of environment, leads to psychophysiological benefits (Celis-Morales et al. 2017; Gidlow et al. 2016). There are perhaps parallels here between this and the notion that walking, at least as a form of transportation, is decreasing in both the Global North and South (Loukaitou-Sideris, 2020), suggesting that walking may have been viewed negatively in our participant group. Further research may wish to explore, qualitatively, if there are further negative, cultural connotations with walking in these non-western settings that perhaps contribute to no subjective benefits in walking in these urban settings. As discussed below, there were positive physiological responses to potentially restorative components of the walk in both locations. Perhaps then the results of the subjective MACL outcome measures reflect the overall experience of the urban typology in each location. Further work should focus on understanding if the built urban settings in these locations are negating the expected benefit of walking on subjective stress and arousal.

While there was no effect on hedonic tone outcomes in Nakuru, we did see benefits of walking on hedonic tone in Udon Thani, with participants who started their walk in the park and ended in the market showing increases in hedonic tone relative to those who completed the walk in a reverse order. This suggests that the order of walking segments in this condition contributed to positive mood more than the reverse combination of walking segments. One explanation for this might be that, in the context of Udon Thani, the role of place may influence these acute mood outcomes. We demonstrate that ending the walk in the market area results in higher hedonic tone levels, which may signify the importance of this public space as a proxy for an increased sense of belonging and community. Previous work has shown the restorative capabilities of indoor and outdoor urban spaces (Barros et al. 2021; Subiza-Pérez et al. 2021), but our own research suggests that the market area is not a space residents seek out to engage in exercise, relaxing or socialising (Tuhkanen et al. 2022). Further work is then needed to understand the potential additive effects of these environmental walking conditions in order to potentially optimize walking routes in this population and in rapidly urbanising cities across the Global South.

In the Nakuru participants, pre-walk MACL outcomes, as expected, predicted post-walk MACL outcomes, but there was no impact on the route order condition nor subjective wellbeing (SWEMWBS) on MACL outcomes. Perceived stress, measures sub-chronically by the PSS, did predict acute hedonic tone, stress and arousal post-walk. In all cases, higher sub-chronic perceived stress predicted increased hedonic tone, stress and arousal in this city setting. This result perhaps suggests that the walks were not of sufficient restorative quality to adequately decrease stress, especially if this stress was already high, but was sufficient to improve positive acute mood. In Udon Thani, as with the Nakuru participants, pre-walk MACL outcomes predicted post-walk MACL hedonic tone and stress levels and approached significance in the arousal condition. Sub-chronic stress appears to have the opposite effect on hedonic tone and arousal outcomes in Udon Thani than in Nakuru, with lower PSS scores in Udon Thani predicting higher hedonic tone and arousal post-walk. Subjective wellbeing, as measured by the SWEMWBS, predicted acute arousal in Udon Thani only, with higher wellbeing leading to higher arousal outcomes, an effect not shown in the hedonic tone or stress outcomes. In both locations, there appears to be an overarching effect of sub-chronic state levels of stress, measured by the PSS, which appear to predict acute stress post-walking. This suggests that there could be a benefit in further understanding community stressors in order to help reduce underlying, longer term stress in these city's populations in order to, potentially, see beneficial effects of short walks.

The real time HRV analyses show clear beneficial effects of nature in both Nakuru and Udon Thani, with the park condition in both locations resulting in higher HRV when compared to other built environments, suggesting lower stress levels in these urban green spaces (Kondo et al. 2018; Sahni, 2012). These results conform with previous stress physiology studies undertaken in Global North settings (Hystad & Cusack, 2019; Roe et al. 2020; Song et al. 2013), suggesting the regional context and cultural preferences that may impact subjective psychological outcomes do not impact physiological responses in the same way. However, we do show potential differences between locations in the stress responses to (busy) public market spaces, with HRV responses in Nakuru suggesting these areas also induce lower stress, as indicated by the higher HRV levels. Similarly, in Udon Thani, the town market segments shows higher levels of HRV, indicating lower stress levels. While we do not see this reflected in the MACL stress outcome in either study location, we do see an increase in hedonic tone in Udon Thani when ending their walk in the marketplace. We must however be cautious about the interpretation of these results when comparing snapshots of subjective mood pre- and post-walk to real-time, unobtrusive, and objective measurement of physiological stress. While there are perhaps qualitative differences in these spaces, both physically and culturally, further research is needed to understand the mechanisms between these differences in stress responses. One explanation might be the presence of people within these respective spaces, with research suggesting restorative effects are more likely to occur in the presence of 'few people' compared to no people or an overcrowded space (Nordh et al. 2011). Further to this, our earlier work has shown that participants may find the market area in Nakuru a stressful place due to fear of crime and traffic congestion, in contrast to the physiological decreases we show in stress responses, as measured by HRV (Cinderby et al. 2021; Tuhkanen et al. 2022). This corresponds with research that suggests that the quality of an urban setting, and subsequent walking experience, directly impacts an individual's intention to walk (Bornioli et al. 2019). Further work then is needed to delineate psychological and physiological benefits and disadvantages in the sample population along with any place, environmental (e.g. climatic) and culturally specific preferences. Further work also needs to address any infrastructure issues that may contribute to the decision to walk in these urban settings (Alfonzo, 2005; Bornioli et al. 2019), which have further policy implications. In South America, research has shown how perceived availability of walking infrastructure (such as pavement quality and crossing opportunities) increases real estate values, such is the importance of residential walkability (Trichês Lucchesi et al. 2021). If research can show how to optimally design an urban space to promote walking behaviours (and subsequently improving public health), this could be vital for planners and policy makers in rapidly urbanising cities and towns across the globe.

Our final analysis, addressing Research Question 2, assessed differences in sub-chronic wellbeing between Nakuru and Udon Thani, as measured by the PSS and SWEMWBS scales. Our results showed clear, statistically significant differences between the two, with participants in Nakuru reporting both higher stress and wellbeing than participants in Udon Thani. Our previous work comparing wellbeing and stress in these countries, albeit in larger cities (Nairobi and Bangkok, respectively) showed the opposite effect, with Thailand (Bangkok) showing higher wellbeing and stress levels than Nairobi (Neale, Besa, et al., 2020). Perhaps these results, in isolation, point to differences between major and secondary cities in these respective countries. We further looked to understand any interaction effects between study location and gender on the PSS and SWEMWBS outcomes and show no significant gender or interaction differences in the SWEMWBS outcomes. However, while we show no significant effect of gender alone on the PSS outcomes, we do see an interaction effect between location and gender. Specifically, females in Udon Thani reported higher perceived stress than their male counterparts, but females in Nakuru report lower perceived stress than their male counterparts. This finding has important implications for understanding how gender differences may influence sub-chronic subjective stress and wellbeing, which in turn appear to directly predict acute-mood outcomes post-walking in urban settings within these countries. However, some caution is needed with the subjective outcomes presented here given the use of Western-developed scales in non-Western countries. Recent efforts from the World Health Organization have looked to understand how to present wellbeing data from culturally diverse areas of Europe (World Health Organization (WHO) 2015, 2016) and this extends into our sites of interest here. Further research is needed to explore optimal measures of wellbeing that can be used both across and within different cultures across the globe, particularly as interest in cross-country comparisons of wellbeing increase.

While these results show interesting, emerging data related to health and wellbeing within both African and Asian secondary cities, we must acknowledge limitations of this work. While we directly compare between the effects of urban space and typologies within each of our city locations, one could argue the need for a control condition or cross-over design in order to understand baseline differences between our samples. This would help to understand, more directly, if the responses we see are culturally specific to the location/participants in question, or if they are universal. Our participants were recruited using convenience sampling at university campuses in each location which may suggest that the socio-economic status of the participants' may not be representative of the location as a whole. While this may impact PSS and SWEMWBS generalisability, it is however unlikely that socio-economic status would significant alter HRV during these walking sessions. While we appreciate the qualitative differences between locations, this protocol allows for both understanding cultural differences in response to urban form as well as being able to optimize public health efforts at a given location. This has further policy implications at local, regional or national levels relating to improving health and wellbeing, in line with the Sustainable Development Goals (#3) at these locations but also across the Global South.

Our previous work indicated Nakuru has a significantly higher number of self-employed and rental tenants compared to Udon Thani where more residents are employed and homeowners (Cinderby et al. 2021). These qualitative differences in employment and residential status may contribute to the wellbeing and stress responses discussed above. In Nakuru, whilst overall affluence is lower, the differences between objective components of wellbeing are not significant apart from at the extremes (wealthiest neighbourhood compared to least affluent). These findings indicate there is greater relative equality in objective wellbeing compared to Udon Thani where socio-environmental conditions are more closely correlated with relative economic affluence.

6. Conclusion

This study shows, for the first time, psychophysical assessment of, and comparison between, urban spaces in secondary cities in Africa and Asia. Our results showed some unusual findings regarding subjective mood that perhaps indicate geographical differences in mood states in response to walking in urban settings relative to consistent findings shown in the Global North. That we also show differences in sub-chronic health and wellbeing outcomes between study locations supports the notion that further work is needed to understand these potential geographical differences and the social mechanisms underpinning them. There appears to be beneficial effects of nature in both study locations, demonstrated by increased heart rate variability in park/natural settings within the urban walks. These results suggest a beneficial effect on stress response that can be important in the development of public health measures as these cities continue to rapidly urbanise.

Author statement

Chris Neale: Conceptualisation, Methodology, Formal Analysis, Data Curation, Writing – Original Draft, Review and Editing, Mehdi Boukhechba: Methodology, Formal Analysis, Writing – Review and Editing. Steve Cinderby: Conceptualisation, Investigation, Methodology, Writing – Review and Editing, Funding Acquisition.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvp.2023.101973.

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