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Physical activity patterns and biomarkers of cardiovascular disease risk in hunter-gatherers

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ABSTRACT

Objectives: Time spent in moderate-to-vigorous physical activity (MVPA) is a strong predictor of cardiovascular health, yet few humans living in industrialized societies meet current recommendations (150 minutes/week). Researchers have long suggested that human physiological requirements for aerobic exercise reflect an evolutionary shift to a hunting and gathering foraging strategy and a recent transition to more sedentary lifestyles likely represents a physical activity mismatch with our past. The goal of this study is to explore this mismatch by characterizing MVPA and cardiovascular health in the Hadza, a modern hunting and gathering population living in Northern Tanzania.

Methods: We measured MVPA using continuous heart rate monitoring in 46 participants recruited from two Hadza camps. As part of a larger survey of health in the Hadza, we measured blood pressure (n=198) and biomarkers of cardiovascular health (n=23) including C-Reactive Protein, Cholesterol (Total, HDL, and LDL), and Triglycerides.

Results: We show that Hadza participants spend large amounts of time in MVPA (134.92 ± 8.6 minutes/day), and maintain these activity levels across the lifespan. In fact, the Hadza engage in over 14 times as much MVPA as subjects participating in large epidemiological studies in the United States. We find no evidence of risk factors for cardiovascular disease in this population (low prevalence of hypertension across the lifespan, optimal levels for biomarkers of cardiovascular health).

Conclusions: Our results provide evidence that the hunting and gathering foraging strategy involves high levels of MVPA, supporting the evolutionary medicine model for the relationship between MVPA and cardiovascular health.

INTRODUCTION

Regular aerobic physical activity is a key element of a healthy lifestyle and is known to prevent disease, enhance well-being, and increase lifespan (Garber et al. 2011; Warburton et al. 2006). In addition, time spent physically inactive is a major risk factor for cardiovascular disease, metabolic disorders, and all-cause mortality (Ekelund et al. 2015; Garber et al. 2011), and is a key driver of health care costs in the United States (Carlson et al., 2015). The effects of exercise on health are not simply due to reductions in obesity, which is traditionally identified as a major risk factor for morbidity and mortality (Ekelund et al. 2015; Myers et al., 2015). For example, results from an epidemiological study of over 300,000 Europeans suggest that low levels of physical activity (PA) may be responsible for twice as many deaths as obesity (Ekelund et al. 2015). Human physiology seems to require modest amounts of aerobic exercise to maintain healthy organ systems.

Researchers have suggested that an evolutionary history that included a highly aerobically active hunting and gathering lifestyle may be responsible for both the physiological benefits of an active lifestyle and the dangers of more sedentary living (Cordain et al. 1998; Eaton and Eaton 2003; Eaton et al. 1988; Lieberman 2013; Lieberman 2015; Malina and Little 2008; Ferraro et al. 2013; Leonard and Robertson 1997; Lieberman et al. 2009; Malina and Little 2008; Pontzer 2012; Raichlen and Polk 2013). Our physiology may be adapted to respond to PA-induced stresses required of this lifestyle, and when met with an inactive life common to many industrialized societies, organ systems (e.g., the cardiovascular system) undergo a reduction in capacity, sometimes predisposing us to chronic diseases (Lieberman 2015). This concept is best described as a PA-mismatch, where our current environment leads to lower PA levels compared with our ancestors.

In support of this mismatch hypothesis, researchers generally invoke observational data showing modern hunter-gatherer populations, and those living in small-scale societies, engage in higher levels of PA than humans living in more industrialized societies (Cordain et al. 1998; Malina and Little 2008; Leonard 2008). However, these analyses have largely depended on ethnographic accounts of activities, rather than objective and quantitative measures of PA. Recent objective measures of activity and energy expenditure present a more nuanced picture of PA in foraging societies, and suggest that groups practicing traditional subsistence may have PA levels within the range of more developed societies (Gurven et al. 2013; Pontzer et al. 2012). In fact, direct measures of energy expenditure using the doubly labeled water technique show that overall total energy expenditures (kCal/day) do not differ in hunter gatherers compared with more urban-living groups after controlling for fat-free mass, age, and sex (Pontzer et al. 2012; Pontzer 2015; Pontzer et al. 2015), raising the possibility that forager PA levels may not be as high as often assumed.

The goal of this study is to measure PA objectively in a group of hunter-gatherers (the Hadza of northern Tanzania) to both characterize activity levels in members of a foraging society and to place these activity levels into the context of cardiovascular health in this population. The Hadza inhabit a highly seasonal woodland - savannah habitat, composed of rocky, uneven terrain, and dominated by *Acacia spp.*, *Commiphora spp.*, and *Adansonia digitata* (Baobab) trees. Those individuals that continue to live in traditional ways capture nearly all of their food from wild resources including hunting large and small game and gathering honey, tubers, berries, baobab fruit, and other plant foods (Marlowe 2010; Wood and Marlowe 2013). This lifestyle requires considerable movement during the day to hunt and gather foods, to collect water, to gather firewood, and to make social visits to neighboring camps (Marlowe 2010; Pontzer et al. 2012; Raichlen et al. 2014).

This study builds on our earlier examinations of Hadza daily energy expenditure (see Pontzer 2012; Pontzer 2015) by using continuous heart rate monitoring to objectively measure and place Hadza PA levels in the context of current exercise guidelines for the United States. In addition, we use multiple datasets examining cardiovascular risk factors in the Hadza to understand the relationship between PA and health at the population level. Current recommendations from the US Office of Disease Prevention and Health Promotion (ODPHP: http://health.gov/paguidelines/) suggest that, to maintain and improve cardiovascular health, adults should engage in at least 150 minutes per week of moderate intensity activity, 75 minutes per week of vigorous intensity, or an equivalent combination of Moderate and Vigorous Physical Activity (MVPA) in episodes of 10 minutes or longer (see Table 1 for definition of intensity levels). Despite the importance of time spent in MVPA for maintaining health (Garber et al. 2011), only a small percentage (<10%) of individuals of all ages in the US engage in the recommended amounts (Tucker et al. 2011). If human physiology responds positively to PA because ancestral lifestyles demanded high amounts of MVPA, then modern hunting and gathering should be associated with levels of MVPA as high or higher than those that produce positive physiological responses in industrialized societies.

METHODS

Heart Rate

We recruited 46 subjects (n_{male} =19; n_{female} =27; mean age 32.7±17.2 years) from two Hadza camps in northern Tanzania (Setako and Sengeli) (see Supplementary Table S1). Subject IDs employed here match those in previously published studies of this sample (Pontzer et al. 2015). Data collection took place over four two-week periods in August-September 2009, May-June 2010, and January 2011, covering rainy and dry seasons at two camp locations. Participants in these camps hunted and gathered at least 90% of their foods from wild resources (Pontzer et al., 2012, 2015). Approval for this research was provided by all governing organizations (Institutional Review Boards at Washington University, St. Louis, Stanford University, Harvard University, Yale University, Hunter College, and the University of Arizona; The Tanzania Commission for Science and Technology [COSTECH] and the National Institute for Medical Research [NIMR] in Tanzania). All subjects provided their informed consent prior to participating in this project.

Subjects wore Garmin Forerunner 205 GPS units with a chest strap to measure heart rate from dawn until dusk. The Garmin Forerunner 205 records HR measurements when there is a change in a measured parameter (HR, latitude, longitude, and elevation). To analyze these data, raw HRs collected at variable time increments were averaged over one-minute intervals. Only data from days where heart rate was measured for 7 hours or more were included in this analysis. Using these one-minute bins, time spent in different activity zones were calculated. Activity zones (light, moderate, vigorous, and high) were defined following Norton et al. (2010) (Table 1). HR_{max} for each participant was calculated using the age-adjusted equation from Tanaka et al. (2001).

Time spent in each activity zone was calculated in two ways. First, total time spent in each zone was summed for each subject for each day, using one-minute bins of HR data. Second, following Barreira et al. (2015), activity "bouts" were analyzed. An activity bout was defined as a period of time during which a given activity level was maintained for at least 10 minutes. Using this method, time spent in a given activity level was included in the total if it fell within a continuous bout of at least 10 minutes' duration. This method makes use of recommendations for engagement in physical activity developed by the United States Office of Disease Prevention and Health Promotion (i.e., MVPA counts towards goal levels if a bout lasts at least 10 minutes). We analyzed time spent in activity zones using both total time and time as a percentage of heart rate monitor (HRM) wear-time.

We explored predictors of time spent in MVPA using linear mixed models to account for the repeated measurements of heart rate from the same subjects over multiple days and included age and sex as covariates in these models. In addition, we examined the possibility that individuals modulate their overall PA by alternating days with high levels of MVPA and days engaged in lower amounts of MVPA. For individuals with five or more consecutive days of HRM data, we tested the hypothesis that individuals alternate days with high and low MVPA using auto-correlations of time spent in MVPA with one, two, or three day lags.

Finally, we used two approaches to evaluate the relationship between HR and total energy expenditure (TEE), measured using data obtained on the same participants from the doubly labeled water method (IAEA 2009; Pontzer et al. 2015; Pontzer et al. 2012). Both of these analyses were performed on a subset of the total sample. First, to examine the effects of MVPA on total energy expenditure (TEE), we used multiple regressions to determine the effects of MVPA on TEE measured with doubly labeled water. Second, we used the Flex-HR method (Leonard 2003) to estimate TEE from calibrated HR data. To calibrate HR to energy expenditure, subjects (n=18; 7F 11M) wore a portable, breath-by-breath respirometry system (Cosmed K4b2) that captured expired air via a lightweight plastic mask and monitored oxygen consumption and CO_2 production. These trials are described in our initial report (Pontzer et al. 2012) and occurred during the same field season as the HR data collection. Briefly, subjects stood for 10 minutes, then performed a series of walking trials at three self-selected walking speeds (slow, normal, and fast) and two running speeds (normal and fast) over a level 150m trackway laid out near camp. Each speed was maintained for a minimum of 4 minutes to attain steady-state aerobic energy expenditure. Some subjects opted not to perform the running trials. HR was also measured simultaneously during these trials, and the ordinary least squares regression for HR against energy expenditure was used to establish subject-specific HR calibrations. Mean HR during standing trials was used as each subject's "Flex HR", and calibration equations were used to convert HR measured during daily GPS follows to kcal/min, following Leonard (2003). For all epochs with HR above the subject's Flex HR, energy expenditure was estimated from their calibration equation. For all epochs with HR below the Flex HR, including any periods when the GPS and HR monitor were not worn (i.e., evening and night), the rate of energy expenditure during the standing trial was used. Flex HR estimates of energy expenditure were then integrated over each 24 hour day to estimate TEE.

Cardiovascular health biomarkers

As part of ongoing long-term fieldwork with the Hadza, team members have collected markers of cardiovascular health across several field seasons to characterize cardiovascular disease risk at the population level. Blood pressure data were collected during three field seasons for a sample of Hadza subjects living in multiple camps (n=198; see Supplementary Table S1). This sample included 30 individuals that are also in the heart rate study, and other individuals currently practicing traditional hunting and gathering, as well as mixed subsistence involving farming and ethno-tourism. Although cardiovascular health marker data were not collected in the same field season as heart rate data collected for this project, they do provide a general view of cardiovascular disease risk in the Hadza population.

As part of the 2015 field season, we used a portable professional blood test device (CardioChek PA®, Polymer Technology Systems, Inc.) to measure blood lipids (n=22) at a camp (Sengeli) that was practicing traditional foraging. This sample included six individuals that were also a part of the heart rate study. The CardioChek meter was calibrated prior to each measurement session. Fingerstick capillary whole blood samples were collected and analyzed using the CardioChek point of care meter following package instructions. Recent work has shown that the CardioChek system provides results that are within 10% of serum reference values for all blood lipids (Donato et al. 2015). Using this system, we measured total cholesterol, HDL levels, triglyceride levels, and calculated

LDL levels from total cholesterol, HDL, and triglyceride values following (Manninen et al. 1992). We use guidelines of the U.S. National Cholesterol Education report to determine risk levels for blood lipids: Total Cholesterol – desirable levels are < 200 mg/dL, high levels are ≥ 240 mg/dL; LDL – optimal levels are < 100 mg/dL, high levels are > 160 mg/dL; triglycerides – normal levels are < 200 mg/dL, high levels are > 400 mg/dL; HDL – desirable levels are ≥ 60 mg/dL, high-risk levels are < 40 mg/dL.

Finally, because previous work has shown that low blood lipid levels in small-scale societies may be related to high levels of infections (Vasunilashorn et al., 2010), we collected blood spots for a sample of subjects from Sengeli in 2015 (n=23) and measured biomarkers of inflammation and infection (C-reactive protein [CRP] and immunoglobulin E [IgE]). As with the blood lipid data, this sample included six individuals that were also a part of the heart rate study. CRP is a measure of inflammation that increases in the presence of infection, but when chronically high, is associated with increased risk of cardiovascular disease (Ridker et al., 2009). IgE levels are associated with allergic reactions and parasitic infections (Vasunilashorn et al., 2010). Finger stick capillary whole blood samples were collected onto Whatman 903 filter paper cards following a standard protocol (McDade et al. 2007) and dried blood spot samples were analyzed at the University of Oregon. Cards were stored at ambient air temperatures. Blood spot samples were analyzed using previously described high-sensitivity enzyme immunoassays (see McDade et al. 2012). We converted dried blood spot (DBS) values of CRP into serum equivalent values using the equation from McDade et al (2012): serum CRP (mg/l) = 1.84 * CRP_{DBS} (mg/l). We converted DBS values of IgE to serum equivalent values using the following equation from Blackwell et al. (2011):

$IgE_{serum}=0.965*IgE_{DBS}-3.458$ (IU/ml).

RESULTS

Overall, participants engaged in high amounts of MVPA (Table 2; Figs. 1 and 2; Supplementary Table S2, S3), far exceeding the ODPHP guidelines for US adults. For both one-minute and ten-minute bouts (analyzed as raw time and as time as a percentage of HRM wear-time), we found that age is a significant predictor of time spent in MVPA (activity levels increase with age), while sex does not have a significant effect on time spent in MVPA (Table 3). There was no evidence that individuals alternate between days with high levels of MVPA and days with low levels of MVPA regardless of how activity levels were defined (one-minute or ten-minute bouts). No individuals had significant autocorrelations (we examined lags of 1, 2, and 3 days) (Supplementary Table S4, S5). It is possible that sample sizes were too small to detect significant correlations. However, the majority correlation coefficients were negative, which was the expected sign (Supplementary Table S4, S5).

Flex-HR estimates of TEE did not differ significantly from DLW measurements ($p=0.18$, $n=18$ subjects, Student's paired t-test; Figure 3). However, the strength of the relationship between Flex HR estimates and DLW measurements was modest and the slope differed significantly from identity (slope=0.49 standard error±0.18, model adjusted $r^2=0.30$, $p=0.01$). With the regression forced through the origin, the standard error of the slope includes 1.0 (slope=1.05 standard error±0.06, model adjusted $r^2=0.12$, $p=0.01$). Using multiple regression, we examined the amount of variation in TEE measured via doubly labeled water explained by the following variables: average time spent in MVPA (raw or as percent of day), fat-free mass, sex, and age. For all calculations of time spent in MVPA, activity was not a significant factor and only fat-free mass explained a significant amount of variation in TEE (Table 4).

We found little evidence of cardiovascular disease risk in the blood pressure sample or the blood biomarker sample. While blood pressure and blood biomarker data were collected at a different time than heart rate data, they provide population-level cardiovascular health context for interpreting physical activity results. Blood pressures in this group were lower, on average, than age-matched samples from the United States (Fig. 4; Table 5). In a linear mixed effects model, age had a significant effect on systolic ($p<0.001$; Estimate ± standard error = 0.35 ± 0.07) and diastolic ($p = 0.027$; Estimate ± standard error = 0.12 ± 0.05) blood pressures, while sex had no effect on either systolic blood pressure ($p=0.562$) or diastolic blood pressure ($p=0.511$).

Blood markers of cardiovascular disease (cholesterol levels and CRP) also do not show any strong evidence of cardiovascular risk. Because the CardioChek system does not provide values of total cholesterol below 100, we provide descriptive data from our small sample (Table 6). From these data, none of our subjects display total cholesterol values that are in a high cardiovascular risk group (i.e., > 200 mg/dl) and only a single subject possessed LDL levels that were over the threshold for optimal scores (<100 mg/dl). Over half of our subjects have HDL cholesterol values in a high-risk category (<40 mg/dl), however combined with low LDL levels, low HDL levels are not considered high risk (Ridker et al. 2010). Serum-equivalent CRP values were low in this sample of Hadza individuals, with ~74% of participants falling below the high-risk threshold of 3 mg/L (Table 6). Immunoglobulin values do not suggest high levels of infection in this population that could play a role in reduced cholesterol levels described above, as more than 75% of participants have values of IgE that fall into the low category (<2000 IU/ml) defined by Vasunilashorn et al. (2010) (Table 6).

DISCUSSION

Unsurprisingly, our results show that individuals practicing a hunting and gathering lifestyle engage in large amounts of MVPA on a daily basis. On average, our subjects engaged in MVPA for ~135 minutes per day, an amount that is well over the levels suggested to promote cardiovascular health by the ODPHP. When examined in ten-minute bouts, as recommended by the ODPHP, Hadza participants still greatly exceed US guidelines, engaging in an average of ~76 minutes per day (surpassing US weekly guidelines within two days). Males and females both exceed ODPHP recommendations by a large amount, with no statistical differences between the sexes. Age does seem to have an effect on time spent in MVPA, corroborating observational and objectively measured data showing older adults in small-scale societies, including the Hadza, continue to engage in moderate intensity physical activity across the lifespan (defined using both subjective and objective measures), with only minor declines in total physical activity (Gurven et al. 2013; Hawkes et al. 1989). Although ours is not the first study to show higher levels of PA in small-scale societies (see Gurven et al., 2013; Madimenos et al., 2010), we provide quantitative data on high levels of cardiac exertion in a group living a traditional hunting and gathering lifestyle.

These levels of PA are generally thought to benefit the cardiovascular system (Archer and Blair, 2011). While our biomarker dataset cannot speak to the cardiovascular benefits of PA at the individual level, we believe the lack of pervasive cardiovascular disease risk in the Hadza is consistent with their overall high levels of engagement in MVPA at the population level. Biomarkers of cardiovascular risk including blood pressure and cholesterol levels fall below clinically relevant risk thresholds, and in general suggest good cardiovascular health across the lifespan compared to populations in the United States. While HDL cholesterol levels are low in this sample, we note that in individuals with low LDL cholesterol levels, low HDL levels are not considered high risk (Ridker et al., 2010). Recent work in other small-scale societies suggests that low levels of cardiovascular disease biomarkers (i.e. blood lipids) are associated with infections (Vasunilashorn et al. 2010). However, with the exception of a single individual (HZ54) there is no strong evidence that our participants were experiencing acute infections (CRP values > 10 mg/L), and, our results are consistent with data from industrialized societies that suggest a strong link between high levels of MVPA and reduced biomarkers of cardiovascular disease risk (see Archer and Blair, 2011). Thus, the Hadza population may be reaping exercise-induced cardiovascular benefits with healthy vasculature and low biomarker risk of cardiovascular disease, similar to the low levels of cardiovascular disease-related biomarkers found in other small-scale societies that practice some level of PA-based subsistence (Liebert et al. 2013; Vasunilashorn et al. 2010).

While our results support the hypothesis that hunter-gatherer MVPA levels are high and are consistent with amounts of MVPA that benefit overall health, our data also continue to support the notion that high PA levels are not associated with high total energy expenditures in this group. Calibrated HR estimates of TEE matched DLW measurements. Pontzer (2015; Pontzer et al. 2016) details a model of TEE that is constrained within an individual or species and malleable over evolutionary time. Although the mechanism is not well understood, high levels of PA for a given individual lead to either changes in non-exercise metabolism (e.g., reductions in energy spent on reproductive activity or somatic maintenance), or alternating periods of activity with rest, such that, in a recent study, high levels of PA did not lead to an associated increase in TEE (see Pontzer et al., 2016). In our sample, there was no relationship between time spent in MVPA and TEE and no evidence that individuals alternate days of rest and activity. Overall, our results are consistent with the hypothesis that high activity levels may be offset in some way and that TEE may be partially constrained within an individual and species.

Comparison with other populations

Previous work has estimated time spent in PA within small-scale societies using a wide variety of techniques, including doubly labeled water (DLW) and factorial methods based on behavioral observation (see Leonard et al., 1997; Pontzer et al., 2012, 2015). These methods have been notoriously problematic since DLW averages energy costs of effort over multiple days and observational methods present difficulties in accurately gauging the level of effort applied to a particular activity by different individuals (Leonard et al. 1997). More recently, researchers have used accelerometry and heart rate to objectively measure PA in non-industrial subsistence contexts (Gurven et al. 2013; Madimenos et al. 2011). Using a combination of heart rate and accelerometry, Gurven and colleagues (Gurven et al. 2013) showed that in Tsimane participants (forager-horticulturalists from the Bolivian Amazon), men had physical activity levels at the high end of a comparison with industrialized societies, while women engaged in lower amounts of PA than men, and fell at an intermediate range of comparative physical activity levels. Additionally, in the Tsimane, older adults spend less of their day in moderate or vigorous activity. Madimenos et al. (2011) measured PA levels using waist-worn accelerometers in the Shuar, a forager-horticulturalist population living in neo-tropical Ecuador. Although the researchers did not break down PA levels by intensity, they did find significantly higher levels of total PA in males compared to females, and did not find any significant effect of age on overall PA levels (Madimenos et al. 2011).

While these studies are the only to our knowledge with direct measures of PA, their results are similar to those found in other small-scale societies with mostly agricultural or pastoral lifestyles that have used indirect estimates of PA (Dufour and Piperata 2008; Kashiwazaki et al. 1995; Lawrence and Whitehead 1988). Contrasting with these results, we found that Hadza participants engaged in large amounts of moderate and vigorous activity overall, that males and females do not significantly differ in time spent in MVPA, and that levels of MVPA may actually increase with age (but see below for interpretation of age-effects). While methodological differences may explain the variance in MVPA among populations, our results suggest hunting and gathering populations may engage in higher levels of MVPA than agriculture-based societies. The lack of sex difference in MVPA among the Hadza is of particular interest since males walk father, on average, each day in this sample (Pontzer et al. 2015; Pontzer et al. 2012). Heart rate monitors capture activities that are upper body-based and likely more prevalent in females (e.g., pounding nuts or digging), but that would not be measured with GPS or waist-worn accelerometry. In addition, females often carry large loads while walking, including offspring, firewood, water, and food (see Marlowe, 2010), which may lead to higher heart rates than expected by analysis of GPS-based walking speed or distance alone.

Our results also suggest that Hadza hunter-gatherers engage in a much larger amount of PA than those living in more industrialized societies. In a comparison of populations from five countries varying in degrees of socio-economic development, time spent in MVPA as measured by accelerometry was considerably lower than we measured in the Hadza participants: Ghana (34.7±23.4 mins/day), South Africa (38.1±33.8 mins/day), Jamaica (26.0±21.7 mins/day), Seychelles (32.5±23.2 mins/day), and Urban Chicago, USA (25.8±31.9 mins/day) (Dugas et al. 2014). Using a very large accelerometry dataset from the National Health and Nutrition Examination Survey (NHANES), Tucker et al. (2011) found that a geographically diverse sample of adults living in the United States engage in, on average, 45.1±4.6 minutes/week of moderate PA and 18.6±6.6 minutes/week of vigorous PA (i.e., just over an hour *per week* of MVPA). By comparison, our data suggest Hadza participants engage in ~805 minutes of moderate PA and ~137 minutes of vigorous PA per week, ~14.8 times higher than adults in the US. Using a slightly older NHANES dataset, Troiano et al. (2008) broke down accelerometry data into time spent in bouts of at least ten minutes. US children spend ~25-45 minutes in MVPA while Hadza children engage in over an hour per day of moderate PA when calculated using the 10-minute bout method. Differences between US subjects and Hadza subjects increase with age. For example, US adults engaged in only ~6-10 minutes per day of MVPA (Troiano et al. 2008). Any way we examine the data, Hadza hunter-gatherers across the lifespan engage in higher levels of MVPA than individuals living in the US.

Age related changes in MVPA

Our data show that older Hadza adults may engage in higher amounts of MVPA than younger individuals, differing from age-related patterns found in other small-scale and industrialized societies. While it is possible that these results reflect increased PA in aging individuals, it is also possible that physiological changes in the relationship between HR and physical activity associated with age influence our results. Maximum HR is known to decline with age (Tanaka et al., 2001), and this rate of decline, derived from Western populations, shapes the standard age-specific cut-offs for MVPA. Because we calculated activity intensities using these age-dependent equations, it is possible that variation in the decline of HRs with age among individuals artificially increases estimates of activity intensity. In addition, while maximum heart rate declines with age, in aerobically trained older athletes, other aspects of physiology mitigate the effects of this decline on exercise performance, including prevention of reductions in maximal stroke volume and enhancing the ability of muscles to extract oxygen from blood (Pollock et al. 1997; Heath et al. 1981). Thus, we believe the most appropriate interpretation of our results is that we do not find evidence of a significant decline in engagement in MVPA in older adults in our sample.

Conclusions

Our results show that Hadza hunter-gatherers spend much higher amounts of time in MVPA than do individuals in more industrialized societies. Along with studies of other small-scale societies, this pattern suggests that our ancestors, who practiced hunting and gathering for ~2.0 million years, were adapted to a lifestyle characterized by long periods of time spent in MVPA. Within the framework of the PA mismatch hypothesis, our results provide some context for understanding the amounts of cardiac stress experienced by hunter-gatherers, and therefore, the stresses that lead to improved cardiac health. It is important to note that diet plays a major role in cardiovascular disease risk, and dietary mismatches described by others are likely responsible in part for lower disease risk hunter-gatherers (Cordain et al. 2005; Eaton et al. 1988). However, as described earlier, PA independently stresses specific organ systems, requiring an expansion of capacity that is often associated with health benefits (Lieberman 2015). In the absence of PA-induced stimuli, reductions in capacity are associated with increased risk of morbidity and mortality. Thus, we believe our reliance on exercise for the maintenance of health is best understood through the lens of our evolutionary history as aerobically active hunters and gatherers. Additional comparative data for other populations would allow us to more fully model plausible activity patterns in human ancestors, but our results support the hypothesis that hunting and gathering requires high levels of MVPA.

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AUTHOR CONTRIBUTIONS

DAR, HP, JAH, JJS, GE, JCB, AS, BMW designed the study and contributed data. AZPM, and FWM contributed essential materials for the research. DAR, HP, JAH, JJS, GE, JCB, AS, BMW wrote the article.

REFERENCES

Archer E, and Blair SN. 2011. Physical activity and the prevention of cardiovascular disease: from evolution to epidemiology. Prog Cardiovasc Dis 53:387-396.

Barreira TV, Hamilton MT, Craft LL, Gapstur SM, Siddique J, and Zderic TW. *In press*. Intra-individual and inter-individual variability in daily sitting time and MVPA. J Sci Med Sport.

Blackwell AD, Gurven MD, Sugiyama LS, Madimenos FC, Liebert MA, Martin MA, Kaplan HS, and Snodgrass JJ. 2011. Evidence for a Peak Shift in a Humoral Response to Helminths: Age Profiles of IgE in the Shuar of Ecuador, the Tsimane of Bolivia, and the US NHANES. PLoS Negl Trop Dis 5.

Carlson, S.A., Fulton, J.E., Pratt, M., Yang, Z., and Adams, E.K. (2015). Inadequate physical activity and health care expenditures in the United States. *Prog. Cardiovasc. Dis.* 57**,** 315-323.

Cordain L, Eaton SB, Sebastian A, Mann N, Lindeberg S, Watkins BA, O'Keefe JH, and Brand-Miller J. 2005. Origins and evolution of the Western diet: implications of iodine and seafood intakes for the human brain - Reply. Am J Clin Nutr 82:483-484.

Cordain L, Gotshall R, Eaton SB, and Eaton 3rd S. 1998. Physical activity, energy expenditure and fitness: an evolutionary perspective. Int J Sports Med 19:328-335.

Donato LJ, Deobald GR, Wockenfus AM, Hornseth JM, Saenger AK, and Karon BS. 2015. Comparison of two point of care devices for capillary lipid screening in fasting and postprandial adults. Clin Biochem 48:174-176.

Dufour DL, and Piperata BA. 2008. Energy expenditure among farmers in developing countries: What do we know? Am J Hum Biol 20:249-258.

Dugas LR, Bovet P, Forrester TE, Lambert EV, Plange-Rhule J, Durazo-Arvizu RA, Shoham D, Kroff J, Cao GC, Cooper RS et al. . 2014. Comparisons of intensity-duration patterns of physical activity in the US, Jamaica and 3 African countries. BMC Public Health 14.

Eaton SB, and Eaton SB. 2003. An evolutionary perspective on human physical activity: implications for health. Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology 136:153-159.

Eaton SB, Konner M, and Shostak M. 1988. Stone agers in the fast lane: chronic degenerative diseases in evolutionary perspective. The American journal of medicine 84:739-749.

Ekelund U, Ward HA, Norat T, Luan Ja, May AM, Weiderpass E, Sharp SJ, Overvad K, Østergaard JN, and Tjønneland A. 2015. Physical activity and all-cause mortality across levels of overall and abdominal adiposity in European men and women: the European Prospective Investigation into Cancer and Nutrition Study (EPIC). The American journal of clinical nutrition 101:613-621.

Ferraro JV, Plummer TW, Pobiner BL, Oliver JS, Bishop LC, Braun DR, Ditchfield PW, Seaman III JW, Binetti KM, and Seaman Jr JW. 2013. Earliest archaeological evidence of persistent hominin carnivory. PloS One 8:e62174.

Garber CE, Blissmer B, Deschenes MR, Franklin BA, Lamonte MJ, Lee I-M, Nieman DC, and Swain DP. 2011. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. Med Sci Sports Exerc 43:1334-1359.

Gurven M, Jaeggi AV, Kaplan H, and Cummings D. 2013. Physical activity and modernization among Bolivian Amerindians. PLoS One 8:e55679.

Hawkes K, O'Connell JF, and Blurton Jones NG. 1989. Hardworking Hadza grandmothers. In: Standen V, and Foley RA, editors. Comparative socioecology of humans and other mammals. London: Basil Blackwell. p 341-366.

Heath G, Hagberg J, Ehsani AA, and Holloszy J. 1981. A physiological comparison of young and older endurance athletes. J Appl Physiol 51:634-640.

IAEA. 2009. Human health series 3: assessment of body composition and total energy expenditure in humans using stable isotope techniques. Vienna: IAEA.

Kashiwazaki H, Dejima Y, Orias-Rivera J, and Coward WA. 1995. Energy expenditure determined by the doubly labeled water method in Bolivian Aymara living in a high altitude agropastoral community. The American journal of clinical nutrition 62:901-910.

Lawrence M, and Whitehead RG. 1988. Physical activity and total energy expenditure of child-bearing Gambian village women. Eur J Clin Nutr 42:145-160.

Leonard WR. 2003. Measuring human energy expenditure: what have we learned from the flex-heart rate method? Am J Hum Biol 15:479-489.

Leonard WR. 2008. Lifestyle, diet, and disease: comparative perspectives on the determinants of chronic health risks. In: Stearns SC, and Koella JC, editors. Evolution in Health and Disease. New York: Oxford University Press. p 265-276.

Leonard WR, Galloway VA, and Ivakine E. 1997. Underestimation of daily energy expenditure with the factorial method: implications for anthropological research. Am J Phys Anthropol 103:443-454.

Leonard WR, and Robertson ML. 1997. Comparative primate energetics and hominid evolution. Am J Phys Anthropol 102:265-281.

Lieberman D. 2013. The Story of the Human Body: Evolution, Health and Disease: Penguin UK.

Lieberman DE. 2015. Is Exercise Really Medicine? An Evolutionary Perspective. Curr Sports Med Rep 14:313-319.

Lieberman DE, Bramble DM, Raichlen DA, and Shea JJ. 2009. Brains versus brawn and the evolution of *Homo*. In: Grine F, and Leakey REF, editors. The Origin of *Homo*. New York: Plenum. p 77-92.

Liebert MA, Snodgrass JJ, Madimenos FC, Cepon TJ, Blackwell AD, and Sugiyama LS. 2013. Implications of market integration for cardiovascular and metabolic health among an indigenous Amazonian Ecuadorian population. Ann Hum Biol 40:228-242.

Madimenos FC, Snodgrass JJ, Blackwell AD, Liebert MA, and Sugiyama LS. 2011. Physical activity in an indigenous Ecuadorian forager□horticulturalist population as measured using accelerometry. Am J Hum Biol 23:488-497.

Malina RM, and Little BB. 2008. Feature Article Physical Activity: The Present in the Context of the Past. Am J Hum Biol 20:373-391.

Manninen V, Tenkanen L, Koskinen P, Huttunen JK, Manttari M, Heinonen OP, and Frick MH. 1992. Joint Effects of Serum Triglyceride and Ldl Cholesterol and Hdl Cholesterol Concentrations on Coronary Heart-Disease Risk in the Helsinki Heart-Study - Implications for Treatment. Circulation 85:37-45.

Marlowe F. 2010. The Hadza: hunter-gatherers of Tanzania: Univ of California Press.

McDade TW, Tallman PS, Madimenos FC, Liebert MA, Cepon TJ, Sugiyama LS, and Snodgrass JJ. 2012. Analysis of variability of high sensitivity C-reactive protein in lowland ecuador reveals no evidence of chronic low-grade inflammation. Am J Hum Biol 24:675-681.

McDade TW, Williams S, and Snodgrass JJ. 2007. What a drop can do: Dried blood spots as a minimally invasive method for integrating biomarkers into population-based research. Demography 44:899-925.

Myers, J., Mcauley, P., Lavie, C.J., Despres, J.-P., Arena, R., and Kokkinos, P. (2015). Physical activity and cardiorespiratory fitness as major markers of cardiovascular risk: their independent and interwoven importance to health status. *Prog. Cardiovasc. Dis.* 57**,** 306-314.

Norton K, Norton L, and Sadgrove D. 2010. Position statement on physical activity and exercise intensity terminology. J Sci Med Sport 13:496-502.

Ong KL, Cheung BMY, Man YB, Lau CP, and Lam KSL. 2007. Prevalence, awareness, treatment, and control of hypertension among United States adults 1999-2004. Hypertension 49:69-75.

Pollock ML, Mengelkoch LJ, Graves JE, Lowenthal DT, Limacher MC, Foster C, and Wilmore JH. 1997. Twenty-year follow-up of aerobic power and body composition of older track athletes. J Appl Physiol 82:1508-1516.

Pontzer H. 2012. Ecological energetics in early Homo. Current Anthropology 53:S346-S358.

Pontzer H. 2015. Constrained total energy expenditure and the evolutionary biology of energy balance. Exerc Sport Sci Rev 43:110-116.

Pontzer H, Durazo-Arvizu R, Dugas LR, Plange-Rhule J, Bovet P, Forrester TE, Lambert EV, Cooper RS, Schoeller DA, and Luke A. 2016. Constrained Total Energy Expenditure and Metabolic Adaptation to Physical Activity in Adult Humans. Curr Biol.

Pontzer H, Raichlen DA, Wood BM, Emery Thompson M, Racette SB, Mabulla AZ, and Marlowe FW. 2015. Energy expenditure and activity among Hadza hunter□gatherers. Am J Hum Biol. 27:628-637.

Pontzer H, Raichlen DA, Wood BM, Mabulla AZ, Racette SB, and Marlowe FW. 2012. Hunter-gatherer energetics and human obesity. PLoS One 7:e40503

Raichlen DA, and Polk JD. 2013. Linking brains and brawn: exercise and the evolution of human neurobiology. Proceedings of the Royal Society of London B: Biological Sciences 280:20122250.

Raichlen DA, Wood BM, Gordon AD, Mabulla AZP, Marlowe FW, and Pontzer H. 2014. Evidence of Levy walk foraging patterns in human hunter-gatherers. Proc Natl Acad Sci U S A 111:728-733.

Ridker PM, Genest J, Boekholdt SM, Libby P, Gotto AM, Nordestgaard BG, Mora S, MacFadyen JG, Glynn RJ, Kastelein JJP et al. . 2010. HDL cholesterol and residual risk of first cardiovascular events after treatment with potent statin therapy: an analysis from the JUPITER trial. Lancet 376:333-339.

Tanaka H, Monahan KD, and Seals DR. 2001. Age-predicted maximal heart rate revisited. J Am Coll Cardiol 37:153-156.

Troiano RP, Berrigan D, Dodd KW, Masse LC, Tilert T, and McDowell M. 2008. Physical activity in the United States measured by accelerometer. Med Sci Sports Exerc 40:181.

Tucker JM, Welk GJ, and Beyler NK. 2011. Physical activity in US adults: compliance with the physical activity guidelines for Americans. Am J Prev Med 40:454-461.

Vasunilashorn S, Crimmins EM, Kim JK, Winking J, Gurven M, Kaplan H, and Finch CE. 2010. Blood Lipids, Infection, and Inflammatory Markers in the Tsimane of Bolivia. Am J Hum Biol 22:731-740.

Warburton DE, Nicol CW, and Bredin SS. 2006. Health benefits of physical activity: the evidence. Can Med Assoc J 174:801-809.

Wood BM, and Marlowe FW. 2013. Household and Kin Provisioning by Hadza Men. Hum Nature-Int Bios 24:280-317.

FIGURE LEGENDS

Figure 1. MVPA in male and female Hadza participants. A. Time spent in MVPA calculated using one-minute bins, B. Time spent in MVPA calculated using ten-minute bins, C. Time spent in MVPA as a percentage of heart rate monitor wear time calculated using one-minute bins, D. Time spent in MVPA as a percentage of heart rate monitor wear time calculated using ten-minute bins.

Figure 2. Age-related changes in MVPA. Each data point represents mean MVPA for one individual. A. Time spent in MVPA calculated using one-minute bins, B. Time spent in MVPA calculated using ten-minute bins, C. Time spent in MVPA as a percentage of heart rate monitor wear time calculated using one-minute bins, D. Time spent in MVPA as a percentage of heart rate monitor wear time calculated using ten-minute bins. Females are shown as blue symbols, males are shown as green symbols. Displayed curves are loess fits.

Figure 3. Comparison of Flex HR and DLW methods for TEE. **A.** DLW TEE versus Flex HR TEE for n=18 subjects. Ordinary least squares regression is shown (y=0.49x + 1330, r^2=0.34), as is the regression (y=1.05x) with the intercept forced through 0,0. Dashed line: x=y. **B.** Male (n=11) and female (n=7) mean±st.dev.

Figure 4. Age-related changes in Systolic (A) and Diostolic (B) blood pressure in Hadza adults. Males are green circles, females are blue circles. C. Prevalence of hypertension by age in the Hadza participants compared with data from the U.S. (NHANES; Ong et al. 2007). Displayed curves are loess fits.

Table 1. Heart rate zones

Activity Type	Heart rate range (% of HR_{max})
light	40-54
moderate	55-69
vigorous	70-89
high	>90

Note: HR_{max} is maximum heart rate calculated following Tanaka et al. (2001).

Table 2. Descriptive statistics for PA levels

	One minute bins			Ten minute bins		
	All mean ± sem	Females mean ± sem	Males mean ± sem	All mean ± sem	Females mean ± sem	Males mean ± sem
Light	221.82 [±12.28]	207.73 [±15.48]	241.85 [±19.59]	167.76 [±10.83]	157.07 [±13.55]	182.96 [±17.64]
Moderate	115.35 [±7.36]	126.54 [±9.87]	99.45 [±10.18]	69.2 [±7.1]	80.22 [±10.37]	53.54 [±7.84]
Vigorous	19.57 [±2.34]	22.98 [±3.5]	14.72 [±2.42]	6.69 [±1.45]	8.51 [±2.02]	4.11 [±1.92]
MVPA	134.92 [±8.6]	149.52 [±11.89]	114.17 [±10.79]	75.89 [±7.73]	88.73 [±11.34]	57.65 [±8.11]
High	4.3 [±0.59]	4.69 [±0.89]	3.76 [±0.7]	14.1 [±3.43]	15.88 [±5.28]	11.56 [±3.68]
% time light	46.83 [±2.07]	45.47 [±2.57]	48.75 [±3.49]	34.85 [±1.95]	33.65 [±2.48]	36.57 [±3.18]
% time moderate	24.78 [±1.49]	27.07 [±1.8]	21.53 [±2.41]	14.45 [±1.41]	16.5 [±1.99]	11.53 [±1.78]
% time vigorous	4.31 [±0.52]	5.11 [±0.75]	3.18 [±0.57]	1.42 [±0.3]	1.78 [±0.41]	0.9 [±0.43]
% time MVPA	29.09 [±1.77]	32.18 [±2.23]	24.7 [±2.63]	15.86 [±1.53]	18.28 [±2.17]	12.43 [±1.87]
% time high	0.96 [±0.14]	1.12 [±0.21]	0.73 [±0.14]	2.75 [±0.64]	3.12 [±0.96]	2.22 [±0.72]

Notes: MVPA is moderate-to-vigorous physical activity. All values are given as either minutes per day, or percent of heart rate monitor wear time. For each variable, an individual average was first calculated and means for individuals are presented above.

Table 3. Linear mixed-effects models of time spent in MVPA

	Parameter	Estimate	Std. Error	df	t	p-value
one minute bins	Intercept	2257.216	1422.060	52.191	1.587	0.118
	sex	2075.512	1276.569	45.832	1.626	0.111
	age	172.736	34.411	45.567	5.020	<0.001
one minute bins as % of wear time	Intercept	0.074	0.046	50.979	1.599	0.116
	sex	0.078	0.042	44.691	1.865	0.069
	age	0.005	0.001	44.774	4.717	<0.001
ten minute bouts	Intercept	13.892	1258.625	47.285	0.011	0.991
	sex	1313.811	1134.587	41.387	1.158	0.254
	age	136.566	30.585	41.492	4.465	<0.001
ten minute bouts as % of wear time	Intercept	0.006	0.042	44.549	0.144	0.886
	sex	0.049	0.038	38.980	1.286	0.206
	age	0.004	0.001	39.457	4.013	<0.001

Table 4. Multiple regression models for Total Energy Expenditure

	one minute bins	one minute bins %	ten minute bins	ten minute bins %
r^2	0.678	0.677	0.699	0.698
F	10.537	10.496	12.189	12.116
p-value	0.000	0.000	0.000	0.000
β FFM	0.887	0.906	0.848	0.871
p FFM	**0.011**	**0.007**	**0.011**	**0.010**
β MVPA	0.000	-0.037	0.000	-0.026
p MVPA	0.718	0.780	0.735	0.863
β age	0.000	0.000	0.000	0.000
p age	0.692	0.607	0.811	0.694
β sex	-0.047	-0.046	-0.052	-0.050
p sex	0.275	0.293	0.222	0.235

Notes: FFM is fat-free mass, MVPA is moderate-to-vigorous physical activity

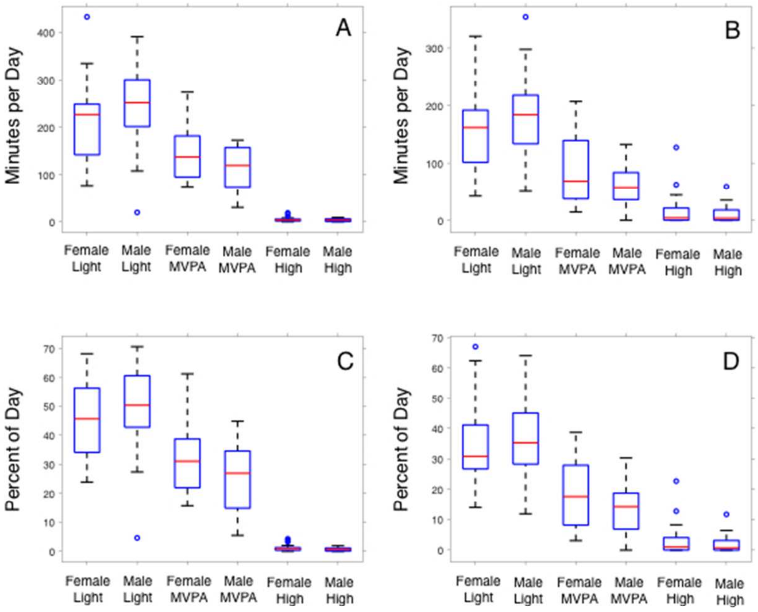
Table 5. Blood pressure statistics for Hadza adults

Sample	N	SBP	DBP	% Hypertensive
Total 18-39	100	115.9 [±14.37]	69.96 [±11.49]	4.95
Female 18-39	53	115.55 [±13.58]	68.83 [±11.37]	3.77
Male 18-39	47	116.3 [±15.36]	71.23 [±11.61]	6.25
Total 40-59	52	123.12 [±19.73]	74.97 [±29.26]	21.28
Female 40-59	27	125.03 [±18.37]	78.12 [±12.07]	22.22
Male 40-59	25	120.6 [±21.51]	70.8 [±12.19]	20.00
Total 60+	27	126.07 [±17.48]	69.63 [±11.28]	25.93
Female 60+	20	128.35 [±16.00]	70.85 [±11.23]	27.78
Male 60+	7	119.57 [±21.15]	66.14 [±11.52]	22.22

Note: Systolic blood pressure (SBP) and diastolic blood pressure (DBP) values are mean [±standard deviation]; Hypertension defined as SBP > 140 or DBP > 90.

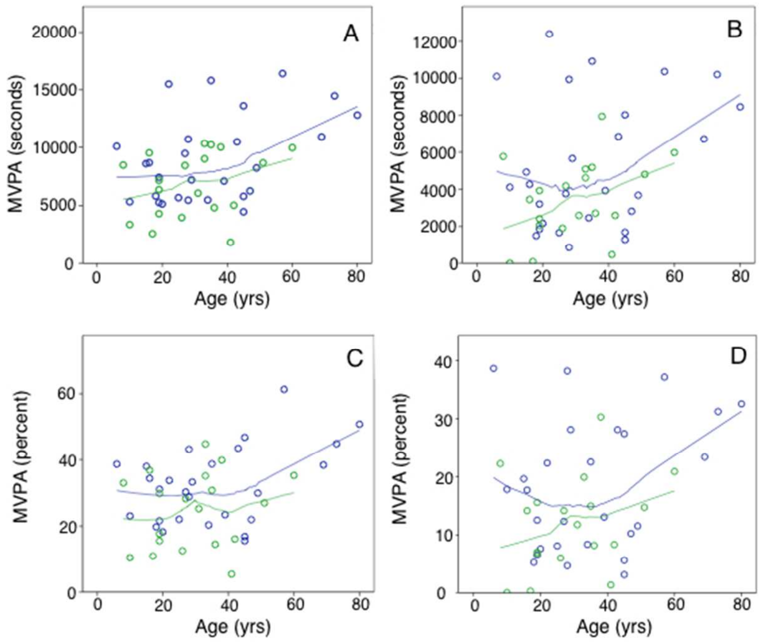
Table 6. Cardiovascular disease biomarkers

ID	sex	age	Total Cholesterol [mg/dL]	HDL [mg/dL]	LDL [mg/dL]	Triglycerides [mg/dL]	Mean CRP [mg/L]	Mean IgE [IU/ml]
HZ52	M	32	<100	33	-	90	0.77	1390.84
HZ53	M	47	<100	38	-	102	3.94	3190.1
HZ54	M	24	<100	<15	-	141	13.41	1052.3
HZ45	M	25	<100	30	-	<50	4.32	3907.44
HZ56	M	29	<100	16	-	118	1.62	1326.75
HZ57	M	56	<100	34	-	125	0.77	1162.62
HZ66	M	78	<100	22	-	57	9.57	1627.85
HZ50	M	24	<100	32	-	75	0.98	3594.6
HZ67	M	36	<100	33	-	<50	1.58	1278.17
HZ29	M	56	100	27	-	<50	1.42	1440.96
HZ63	F	19	107	36	54	81	0.24	617.66
HZ64	M	24	107	34	60	62	2.04	789.51
HZ59	M	31	111	38	61	60	1.21	983.83
HZ58	M	20	115	33	71	68	0.75	2889.4
HZ32	F	24	117	39	53	125	0.39	2360.46
HZ13	F	49	118	42	60	74	0.64	798.78
HZ61	F	61	123	51	-	<50	4.49	6167.04
HZ65	M	18	125	31	78	85	3.48	1298.06
HZ60	F	50	140	41	86	69	1.49	676.58
HZ33	F	51	149	59	76	64	0.24	646.56
HZ62	F	20	165	41	113	55	1.82	1554.06
HZ55	M	46	172	34	115	122	1.49	1533.4
HZ68	M	42	-	-	-	-	1.56	1380.72



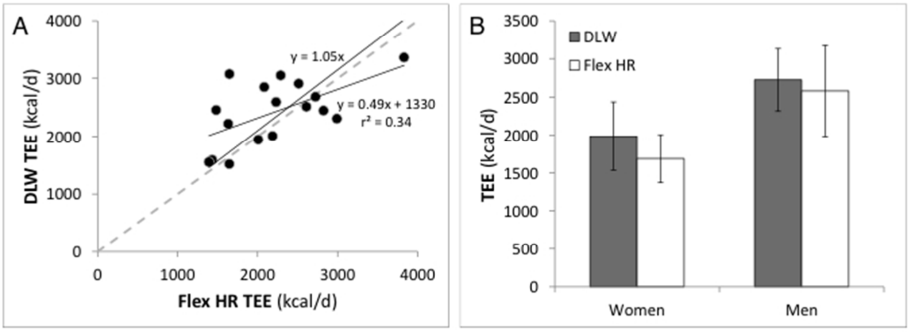
MVPA in male and female Hadza participants

254x190mm (72 x 72 DPI)



Age-related changes in MVPA

254x190mm (72 x 72 DPI)



Comparison of Flex HR and DLW methods for TEE.

254x190mm (72 x 72 DPI)

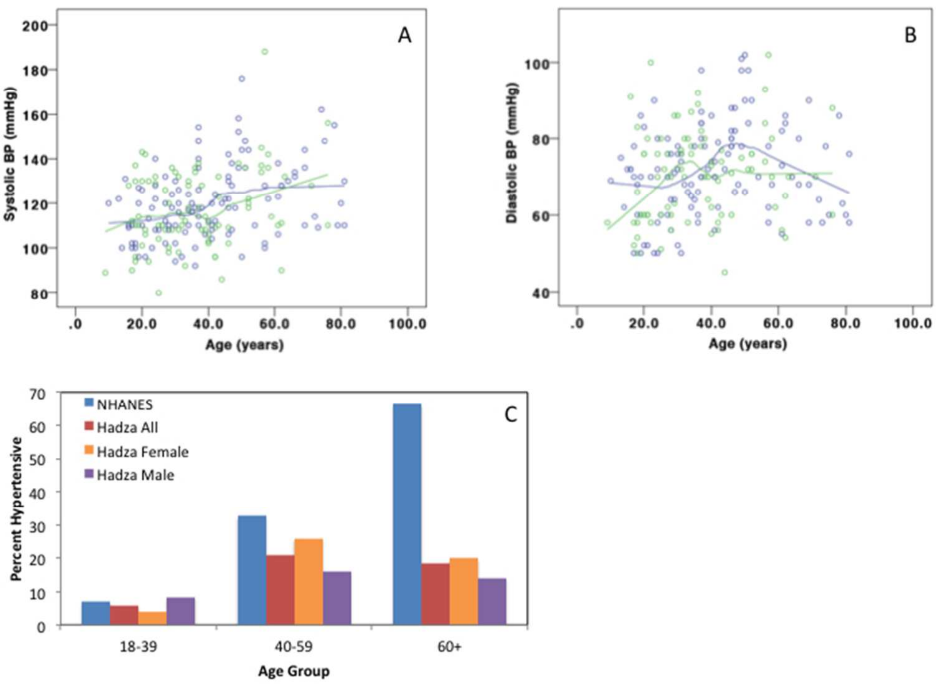


Figure 4. Age-related changes in Systolic (A) and Diostolic (B) blood pressure in Hadza adults.

254x190mm (72 x 72 DPI)