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Science

Variation in human water turnover associated with environmental and lifestyle factors

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See the supplementary materials.

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Abstract:

Water is essential for survival, but one in three individuals worldwide (2.2 billion people) lack access to safe drinking water. Water intake requirements largely reflect water turnover, the water used by the body each day. We investigated the determinants of human water turnover in 5,604 people aged 8 days to 96 years from 26 countries using isotope tracking (^{2}H) methods. Age, body size, and composition were significantly associated with water turnover as were physical activity, athletic status, pregnancy, socioeconomic status, and environmental characteristics (latitude, altitude, air temperature, and humidity). People in countries with low human development index (HDI) had higher water turnover than people who lived in countries with high HDI. Based on this extensive dataset we provide equations to predict human water requirements in relation to anthropometric, economic, and environmental factors.

One Sentence Summary:

Measures of human water turnover from a large global database demonstrate the effects of body size, age, lifestyle, and climate.

Main text:

Water is essential for life (*1*) and daily water intake is necessary to prevent dehydration (i.e., net loss of body water) in most terrestrial animals, including humans (*2*). Total body water (L) is homeostatically controlled (*3*) and tightly regulated day-to-day by thirst and hunger drives leading to intake of fluids and food to offset water losses (*4*). Body water is lost as urine, insensible transcutaneous evaporation and sweat loss, respiratory water vapor, and water in feces (**Fig. 1A**). To maintain water balance, these losses must be matched by intake of water from liquids (drinking water and beverages) and foods (*5, 6*), water vapor in respiratory air intake, transcutaneous water uptake, and water formed during aerobic respiration and metabolism (**Fig. 1A**) (*2, 7*). The total movement of water through the body, both intake and loss, is called water turnover (L/day).

Despite adaptations to minimize dehydration, humans can survive for only ~3 days without consuming water (*1*). The risk of dehydration is greater under conditions requiring increased respiration, blood circulation, and sweating, such as vigorous physical activity or in hot and humid environments (*3*). Insufficient water intake is a risk factor for heat stroke, urinary and kidney diseases, and cardiovascular failure (*8, 9*). An understanding of water turnover and its determinants is critical for global public health decision-making regarding the provision of drinking water and water-enriched food (*10*).

Public health officals need to be able to anticipate future daily water intake demands of their populaions, especially during periods of impeding crisis. Ideally this would be based on scientific evidence regarding the levels of normal water intake. The current recommended intakes for water (*8*, *9*, *11*), however, rely on epidemiologic self-reported surveys or laboratory-based physiological studies with rather small sample sizes. Results obtained from self-reported intake surveys show large variation linked to imprecision in the assessment method. It is thus difficult to establish clear guidelines for worldwide public health actions from these sources of information. The majority of people who lack access to safely managed drinking water live in countries with a low human development index (HDI), but few studies have examined water turnover in those populations (*2*). To develop global guidelines for daily water intake, empirical measurements of water turnover under free-living conditions are required across a broad range of economic and environmental conditions.

We report water turnover (**Fig 1**) and total body water for 5,604 (3,729 females and 1875 males) people, aged between 8 days to 96 years, from 26 countries around the globe, across a wide range of environments and living conditions (**Fig. S1** and **Table S1**). We used the hydrogen isotope dilution and elimination technique, which provides an objective, accurate, reliable, and precise measurement of both total body water and water turnover under free-living conditions (**Fig. 1B**) (*7*). This method involves the subject drinking about 100 mls of water that is enriched with about 5% deuterated water (DHO). The deuterium floods into the body water pool providing an estimate of total body water via the dilution principle (*12*). The excess deuterium isotope is then eliminated from the body by the elimination routes detailed in **Fig 1A**. Because there is no enriched isotope tracer entering the system the isotope enrichment declines exponentionally back to the baseline level. The rate constant of this exponential return to baseline multiplied by the body water pool is equal to the water turnover.

Data were obtained from the International Atomic Energy Agency doubly labeled water (DLW) Database (*13, 14*). The current study aimed to examine (1) the dependence of water turnover and total body water on age, body size, body composition, total energy expenditure (MJ/d), and physical activity level (PAL = total energy expenditure/basal energy expenditure) through the human lifecourse, (2) the effects of climate, including latitude, altitude, outside air temperature, and humidity; and (3) the potential influence of economic development as measured by the HDI.

Water turnover was greatest in individuals aged 20 to 30 yr in men, and from 20 to 55 yr in women (**Fig. 2A** and **Table S2**). Water turnover was lower in men aged >40 and women aged >65. Total body water was also highest for adults 20 to 40 years old (**Fig. 2B**). As a fraction of total body water, water turnover was highest in neonates (28.3 ± 7.2% per day) and decreased with age to 9.9 ± 3.0% per day in adults aged 18 to 40 years (**Fig. 2C**). Total body water as a proportion of body weight also decreased with age, from 60.0 ± 6.4% of body weight from birth to 6 months to 50.4 ± 5.3% (males) and 42.0 ± 4.8% (females) at age 60 (**Fig. 2D**). Sex differences and the relationship with age and total body water in adults largely reflected variations in percent body fat, which contains less water than muscle and other organs. The ratio of water turnover to total energy expenditure was 0.33 ± 0.09 L/MJ (1.4 ± 0.4 ml/kcal) for adults, comparable to previous isotope-based measures (*15*) (**Fig. 2E).**

Body size and composition, energy expenditure, and climate variables were all correlated with water turnover. Limiting our analysis to adults aged 18 to 60 years to avoid strong age effects (as shown in Fig. 2), bivariate analyses showed that water turnover was positively correlated with fat-free mass, total energy expenditure, and PAL, and negatively correlated with percent body fat ($P<0.001$) (**Fig. 3A through D**). We found a significant curvelinear relationship between outdoor air temperature and water turnover and a curvelinear relationship between latitude and water turnover ($P<0.001$) (**Fig. 3E, F**). Air temperature was positively correlated with water turnover when it was higher than 10 °C ($P<0.001$). Daily water intake was highest at approximately 0° effective latitude and the lowest at -50° or +50° latitude. People living above the Arctic Circle had higher water turnover than those who lived at -50° or +50° latitude.

Linear regression analysis showed that age, fat-free mass, PAL, air temperature, relative humidity, HDI, and altitude were significant predictors of water turnover in adults aged 18 years and older (**Table S3**). We conducted multiple regression analysis (including first- and second-order polynomial terms) to examine potential non-linear relationships between water turnover and the above variables in adults aged 18 years and older (**Table S4**). The positive coefficient of the second-order term of air temperature indicated a curvilinear relationship between water turnover and air temperature. The negative coefficient of the second-order term of age also indicated a curvilinear relationship between water turnover and age. A non-linear increase of water turnover with increase of air temperature is predicted from the standard Scholander curve (*16*) for the impact of ambient temperature on metabolic rate and evaporative water loss. In an additional test of these relationships, repeated measures for 72 people in spring and summer indicated higher water turnover in the summer (mean air temperature of 29 °C) than in spring (mean air temperature of 18 °C) ($P<0.001$), whereas total energy expenditure did not differ seasonally (**Fig. 4A and 4B**).

Water turnover of pregnant and lactating women is of interest because pregnant women have higher total body water and fat-free mass than do non-pregnant women (*17*), and lactating women also lose water via milk production (*11*). Repeated measures of 63 women indicated water turnover increases in the third trimester of pregnancy (+670 mL/d) and during lactation (+260 mL/d) compared to pre-pregnancy (**Fig. 4C**) (*17*). The increase of water turnover during pregnancy is consistent with the increase in total body water.

The highest water turnovers in our sample are consistent with the effects of temperature, climate, physical activity and body size. Nine of the 1,875 males had high water turnover greater than 10 L/d; of these four were athletes, four were adult Shuar forager-horticulturalists of Amazonian Ecuador (*18*), and one male was Caucasian with normal BMI but measured in the summer with a maximal air temperature of 31.7 °C. Thirteen of 3,729 females had high water turnover greater than 7 L/d; of these five females were athletes, two females were pregnant women who had extremely high BMI (>45 kg/m^2) and were measured in the summer; three females had high BMI (>30 kg/m^2), in which two were measured in the summer. Three females were measured in summer, with a maximal air temperature of >30°C.

Lifestyle had clear effects on water turnover. Athletes had higher water turnover than non-athletes (P<0.001, **Fig. 5A** and **Table S5**). Hunter-gatherers, mixed farmers, and subsistence agriculturalists all had higher water turnover than those in industrialized economies (P<0.001, **Fig. 5B** and **Table S6**). People in countries with low HDI had higher water turnover than those who lived in countries with middle and high HDI, even after adjustment for physiological and environmental variables (P<0.001, **Fig. 5C** and **Table S7**).

The effects of body size, PAL, and air temperature were greater for people in countries with low HDI (**Fig. 4D through F**). The smaller effects for these variables in high HDI populations suggests water needs are buffered against environmental influences through effective indoor climate control (*e.g.*, air conditioning). In high HDI countries with access to air-conditioning and heating, people are exposed primarily to a narrow indoor temperature in range (18 to 25 °C) (*19*). By comparison, people living in low HDI countries are more likely to be exposed to ambient environmental temperatures without climate control. This view is consistent with greater size-adjusted water turnover for hunter-gatherers and manual laborers when compared to sedentary adults in industrialized countries (*2*). Similarly, a previous comparison of regional water use (*20*) noted that water use is relatively high in Africa and relatively low in Europe, and results from our analysis may help to explain why.

We obtained the following equation to predict water turnover (**Fig. 6**):

$$\text{Water turnover (mL/d)} = 1076\times\text{PAL} + 14.34\times\text{Body weight (kg)} + 374.9\times\text{Sex} + 5.823\times\text{Humidity (\%)} + 1070\times\text{Athlete status} + 104.6\times\text{HDI} + 0.4726\times\text{Altitude (m)} - 0.3529\times\text{Age}^2 + 24.78\times\text{Age (y)} + 1.865\times\text{Temperature}^2 - 19.66\times\text{Temperature (°C)} - 713.1 \quad \text{[eq.1]}$$

Sex is 0 for female and 1 for male; Athlete status is 0 for non-athlete and 1 for athlete; HDI is 0 for high HDI countries, 1 for middle HDI countries, and 2 for low HDI countries. This equation explains 47.1% of the variation in water turnover. An increase in PAL of 1.0 induces a ~1000 ml increase in water turnover; a 50 kg increase in body weight induces a ~700 ml increases in water turnover; a 50% increase in relative humidity induces a ~300 ml increase in water turnover; and a 1000 m increase in altitude induces a ~500 ml increase in water turnover. Males exhibit ~400 ml more water turnover than do females of the same weight because males have greater fat-free mass and a lower percentage body fat. People who live in low HDI countries exhibit ~200 ml more water turnover than people who live in high HDI countries after controlling for the other measured variables. Athletes have ~1000 ml more water turnover than do non-athletes with everything else being equal. A U-shaped relationship between water turnover and air temperature shows ~1000 ml more water turnover at +30 °C air temperature than the nadir between ±0 and +10 °C air temperature, and also ~400 ml more water turnover at –10 °C air temperature than that nadir. A curvilinear relationship between water turnover and age shows the peak water turnover is shown between 20's and 40's and decrease after 50's and ~700 ml less water turnover at age 80 than at age 30.

A 20-year-old male weighing 70 kg, who is not athletic and exhibits a PAL of 1.75, and who lives in a high HDI country at 0 m altitude where mean air temperature is 10°C and relative humidity is 50%, has a predicted water turnover of 3.2 L/d. A non-athletic 20-year-old female weighing 60 kg living at the same location will have a water turnover of 2.7 L/d. In contrast, a 20-year-old athletic male weighing 70 kg, with a PAL of 2.5, who lives in a high HDI country at a location 2000 m above sea level, where air temperature is 30°C and relative humidity is 90%, has a water turnover of 7.3 L/d; for a 60 kg athletic female in the same scenario, water turnover is 6.8 L/d. In this equation, we used weight and sex as a proxy of fat-free mass because body composition is not easily measured in daily setting. If body composition can be assessed, the following equation can be used to predict water turnover (**Fig. 6**):

$$\text{Water turnover (mL/d)} = 861.9\times\text{PAL} + 37.34\times\text{Fat-free mass (kg)} + 4.288\times\text{Humidity (\%)} + 699.7\times\text{Athlete status} + 105.0\times\text{HDI} + 0.5140\times\text{Altitude (m)} - 0.3625\times\text{Age}^2 + 29.42\times\text{Age (y)} + 1.937\times\text{Temperature}^2 - 23.15\times\text{Temperature (°C)} - 984.8 \quad \text{[eq.2]}$$

TEE was not included into the equations because sex, body weight or PAL capture the variance explained by TEE. When fat-free mass was included in the model, the effect of sex was not significant. The sex difference of water turnover can be explained by the sex difference of the fat-free mass/body weight ratio.

Values of water turnover in this study represented average values under normal conditions. Many health conditions, including parasitic infections and diarrhea, affect water loss and intake (*21*). Additionally, the current study did not assess any indicators of hydration status and did not indicate whether the participants were adequately hydrated. Older adults or vulnerable individuals have a higher risk of both acute and chronic dehydration (*22*, *23*) because they have a decreased thirst response. Medications, anorexia or frailty, and low total body water (storage) are associated with a lower skeletal muscle mass (*i.e.*, sarcopenia). Skeletal muscle tissues contain a large volume of water, particularly in the intracellular space (*24*). Mean water turnover values presented here are not necessarily representative of all people or conditions (*21*) but provide a comparative framework for investigating water intakes in populations with greater needs.

Objective measures of water turnover from a large global dataset indicate that water turnover is strongly related to anthropometric, lifestyle, and environmental factors. We found significant correlations between water turnover and several known markers of health, wellness, and disease risks: Water turnover is positively correlated with fat-free mass, TEE, PAL, athletic status, and negatively correlated with percent body fat and age in adults. Water turnover may therefore provide a useful, integrative biomarker of metabolic health. Biomarkers that capture global metabolic health are generally lacking and of potentially enormous value for public health and medical management.

As shown in Figure 1, we need to be aware that water turnover obtained by the hydrogen isotope dilution and elimination technique is not equal to daily water intake from liquids and foods. Metabolic water accounts for ~10% of water turnover, and respiratory water uptake and transcutaneous water uptake each account for 2 to 3% of water turnover. Therefore, daily water intake from liquids and foods is equivalent to ~85% of water turnover (*7*). An unsolved question is, what percentage of water intake comes from food? Self-reported surveys around the world suggested 20-50% of daily water intake is from food (*5*, *6*, *11*). These estimates, however, are questionable because many studies that have demonstrated self-reported surveys underestimate energy, protein and salt intake. Thus, dietary survey methods probably also underestimate the water intake in food and overestimate from drinking water and beverages. Conversely, if people consume a higher energy density diet with lower water content (*25*, *26*), they may need more water from drinks and beverages. Without measured water intakes from food, it is not possible to assess the relative contributions of food and drinking water or beverages to water turnover in this study, and indeed no studies to date have adequately addressed this issue. Nonetheless, the current study clearly indicates that one size does not fit all for drinking water guidelines, and the common suggestion that we should drink 8 × 8oz glasses of water per day (approx. 2 L) is not backed by objective evidence.

We provide equations to predict human water turnover by environmental, lifestyle and anthropometric factors guided by a large dataset. Improved guidelines are of increasing importance because of the explosive population growth and climate change the world currently faces, which will affect the availability of water for human consumption (*27*, *28*) and non-ingestive uses, such as irrigation, cooling, and manufacturing (*29*). Presently, 2.2 billion people lack access to safe drinking water (*30*). The water turnover measures here can help shape strategies for drinking water and water-enriched food management as the global population and climate changes.

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Acknowledgments

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Figure legends

Fig. 1. (A) Conceptual diagram showing sources of water influx and efflux on human body. * Metabolic water produced inside a living organism as an end product of the oxidation of energy-containing substances in their food. **(B)** Hydrogen isotope dilution and elimination provides an objective measure of total body water (TBW) and water turnover (WT). DLW; doubly labeled water.

Fig. 2. Relationships between age and total body water (TBW) or water turnover (WT) in 3729 females (orange) and 1875 males (blue) aged 0 to 96 years with mean and SD. **(A)** displays WT (L/d), **(B)** TBW (kg), **(C)** WT per TBW (%), **(D)** TBW per body weight (%), **(E)** WT per total energy expenditure (TEE) (L/MJ), or **(F)** TEE (MJ/d). Water turnover increases with age until about 30 years and is higher in men (4.3 L/d) than women (3.4 L/d). Water turnover significantly decreases after 30 years in men and 55 years in women, reaching an average water turnover of 3.1 and 2.8 L/d in men and women aged over 70 years, respectively. The average water turnover rate as a percent of total body water is a maximum of ~25% in neonates, decreases with development, and is ~15% in 5-year-old children. At puberty, water turnover falls to ~10% and remains constant until age 40 years in men and 65 years in women, after which it decreases. The average water turnover per TEE is about 0.33 L/MJ (~1.4 ml/kcal) in adults. Note that the variation in water turnover is incredibly large – the low end for men and women is ~1-1.5 L/day while the upper end is around ~6 L/day – and the outliers lie in the 10L/d range. On average, water accounts for 60% of the body weight in infants, 50% in older adults, and only 42% in women at 60 years of age, reflecting a larger % body fat.

Fig. 3. Relationships between water turnover (WT) against (A) fat-free mass (FFM), (B) percent body fat, (C) total energy expenditure (TEE), (D) physical activity level (PAL), (E) air temperature, and (F) effective latitude in 1657 females (upper panels; red) and 1013 males (lower panels; blue) aged 20 to 60 years. The blue line represents generalized additive models with integrated smoothness (GAM). Pearson correlation analysis shows positive correlations between water turnover and fat-free mass ($r = 0.442$, $P < 0.001$), TEE ($r = 0.488$, $P < 0.001$), PAL ($r = 0.388$, $P < 0.001$), and altitude ($r = 0.100$, $P < 0.001$). Water turnover was negatively correlated with percent body fat (-0.311, $P < 0.001$). Outdoor air temperature was only weakly correlated with water turnover in the whole sample ($r = 0.160$, $P < 0.001$). A significant curvilinear relationship between water turnover and the air temperature and a significant curvilinear relationship between water turnover and effective latitude was observed (see text for details). Average water turnover reached the highest values at around 0° and the lowest at around -50° or +50° of effective latitude. People who lived near the Arctic Circle had higher average water turnover than those who lived around -50° or +50° of effective latitude.

Fig. 4. (A) Repeated measures of 72 people (31 females and 41 males) shows water turnover (WT) was significantly higher in the summer (3.7 ± 1.0 L/d) with an average temperature of 29°C than in the spring (3.0 ± 0.7 L/d) with 18°C ($P < 0.001$). **(B)** In contrast, total energy expenditure (TEE) was not significantly different between summer and spring ($P = 0.233$). **(C)** Repeated measures of 63 pregnant women show that total water turnover was significantly higher during late pregnancy and lactation (data from Butte *et al*. 2005). (Pre = Before pregnancy; Post = 27 weeks postpartum).

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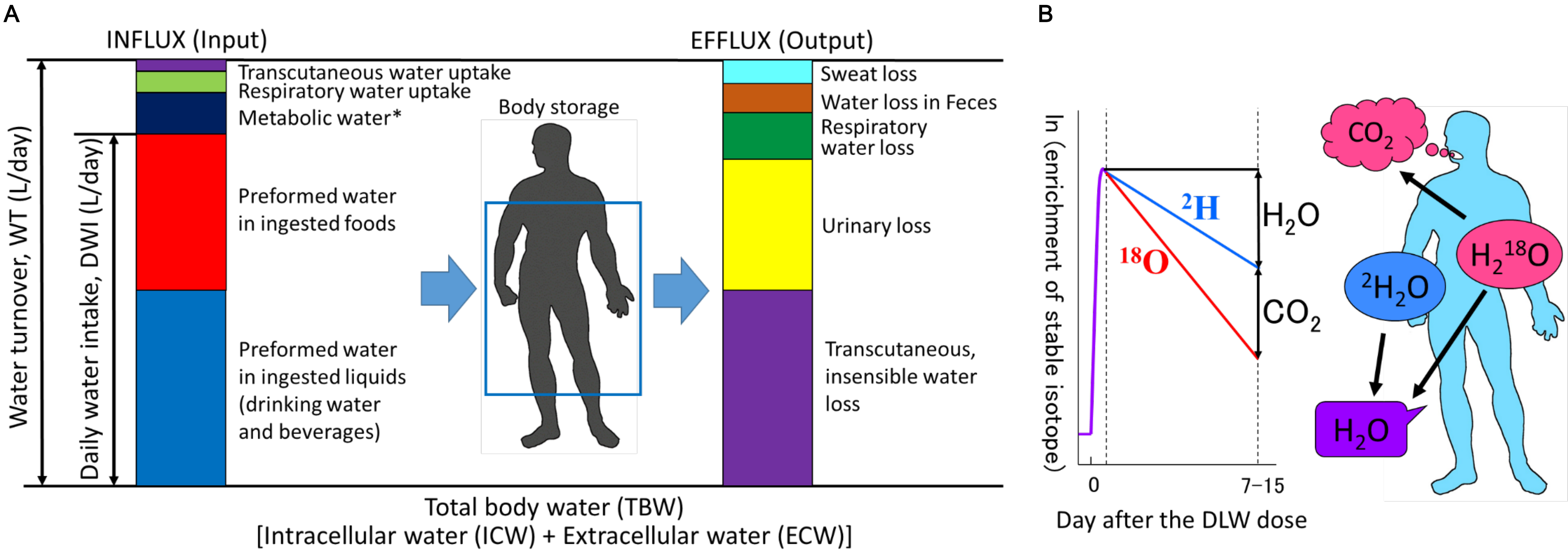
Fig. 6. Determinants of human water turnover. Objective measures of water turnover from a large global dataset indicate that water turnover is strongly related to anthropometric, lifestyle, and environmental factors. PAL = Physical activity level (Total energy expenditure/Basal energy expenditure), HDI = Human development index.



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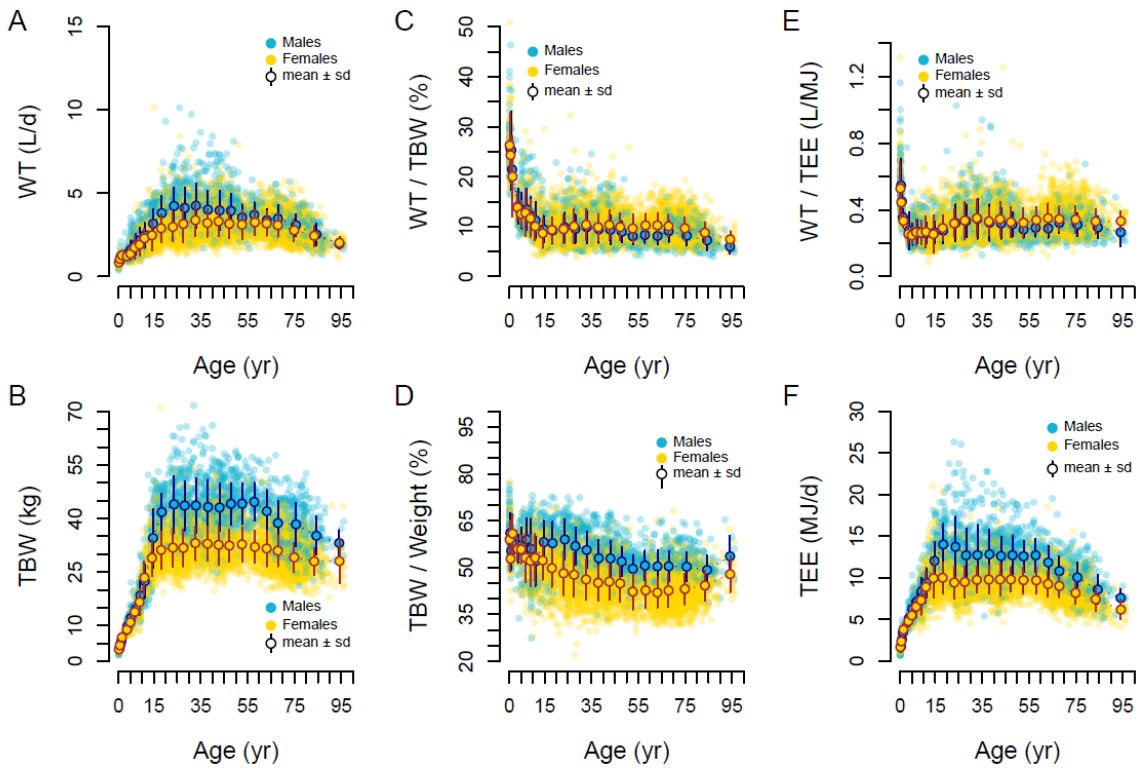

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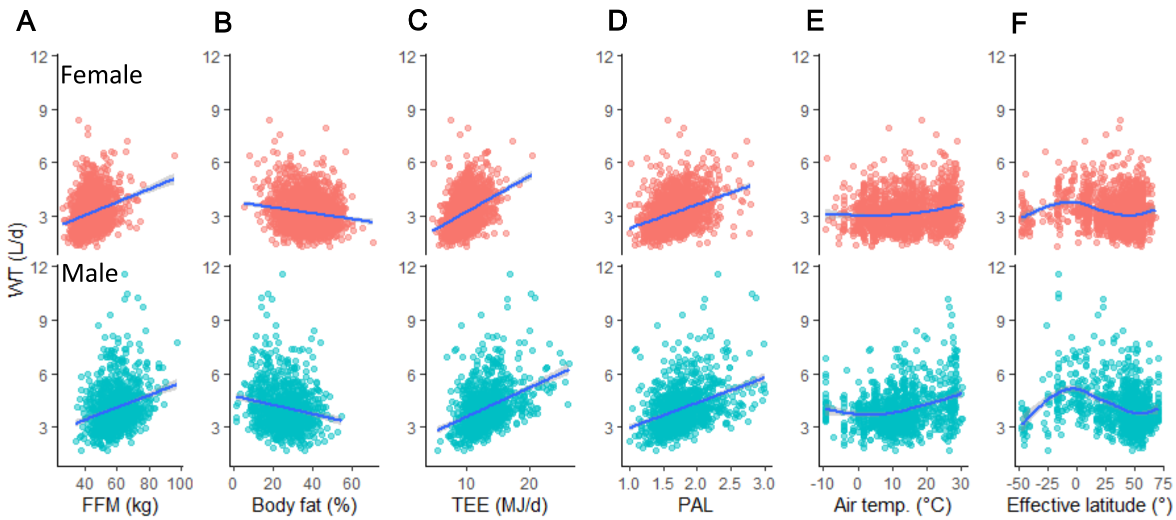

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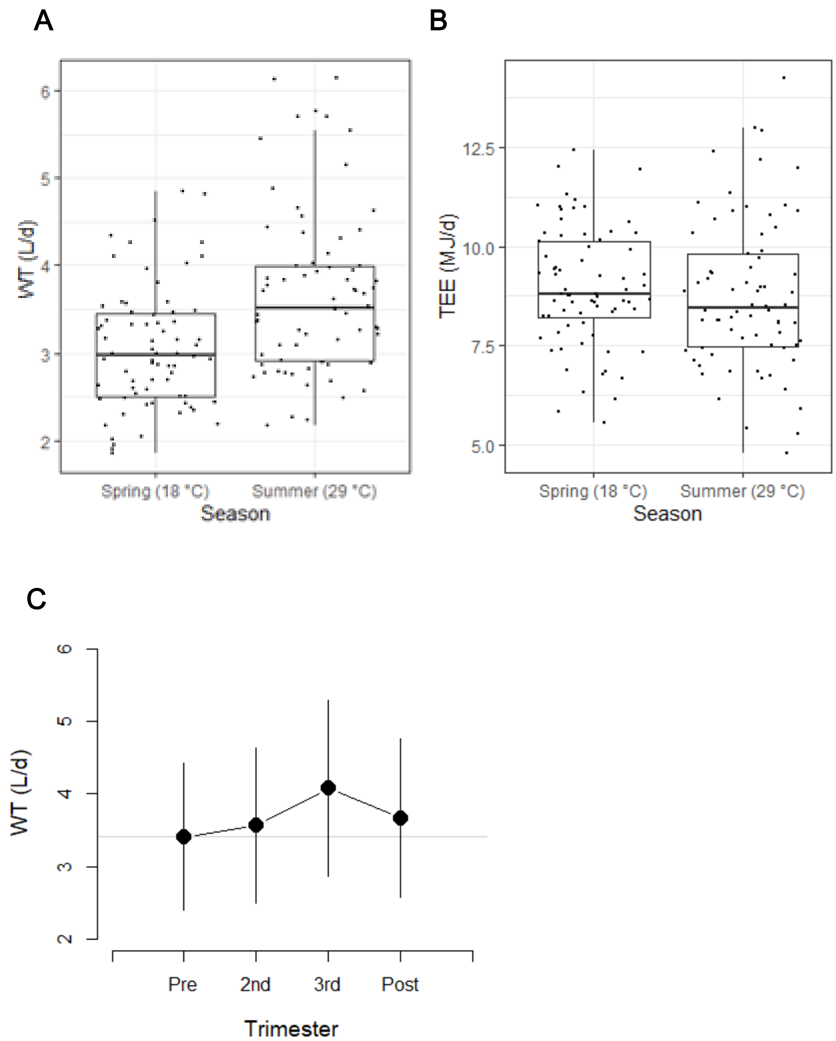

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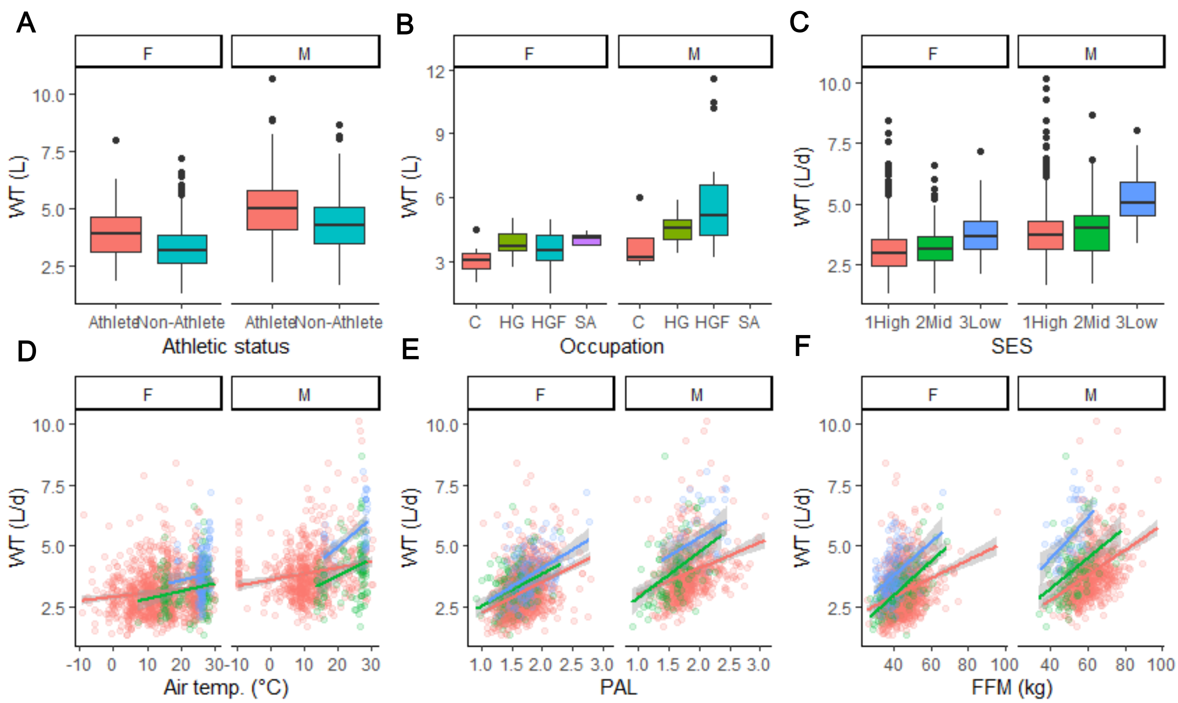

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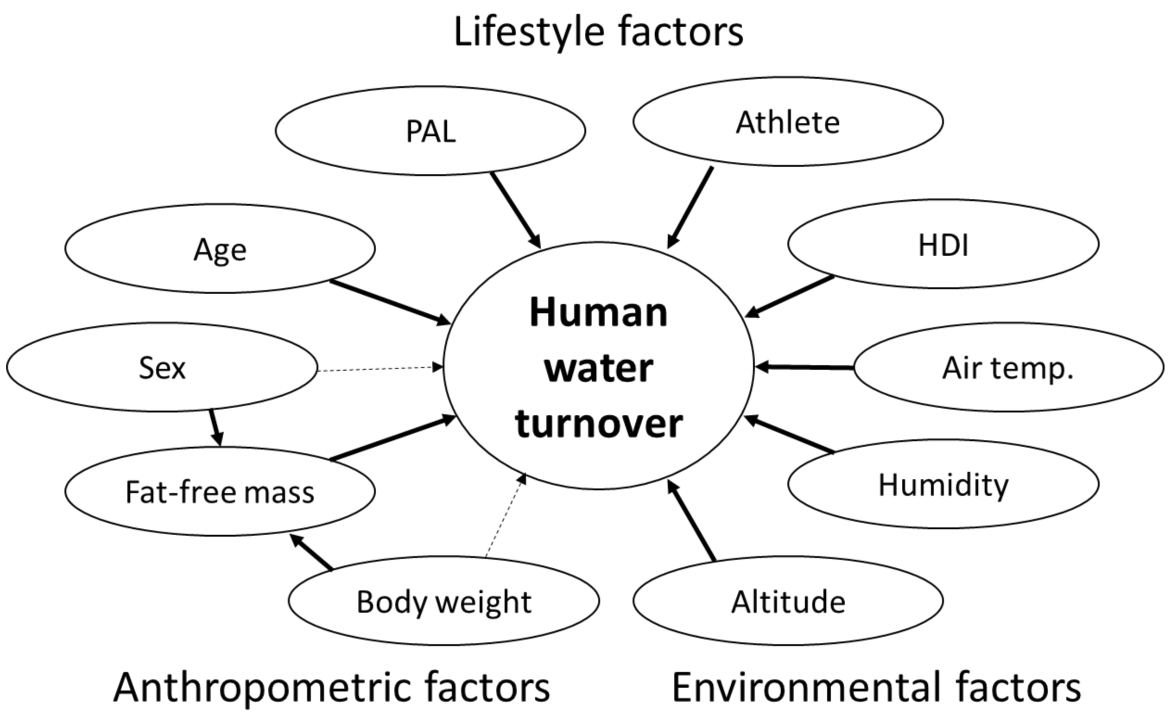

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Supplementary Materials for

Variation in human water intake associated with environmental and lifestyle factors

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The PDF file includes:

Materials and Methods
Fig. S1
Tables S1 to S9
IAEA DLW Database Consortium Collaborators List
References

Other Supplementary Material for this manuscript includes the following:

MDAR Reproducibility Checklist

Materials and Methods

Participants

This analysis was conducted using the International Atomic Energy Agency International Doubly Labeled Water database (IAEA DLW database). The details of the database have been described elsewhere (*31*), and the information is available on the IAEA website (*32*). We used the database version 3.5.3, which had a total of 7049 measurements, of which we analyzed a total of 5604 subjects (3729 females and 1875 males). These subjects had no missing information on age, sex, height, weight, dilution spaces, and elimination rates of ^{18}O and ^{2}H, total energy expenditure (TEE), water turnover (WT), fat-free mass (FFM), fat mass (FM), measurement data, latitude, longitude, and climate data.

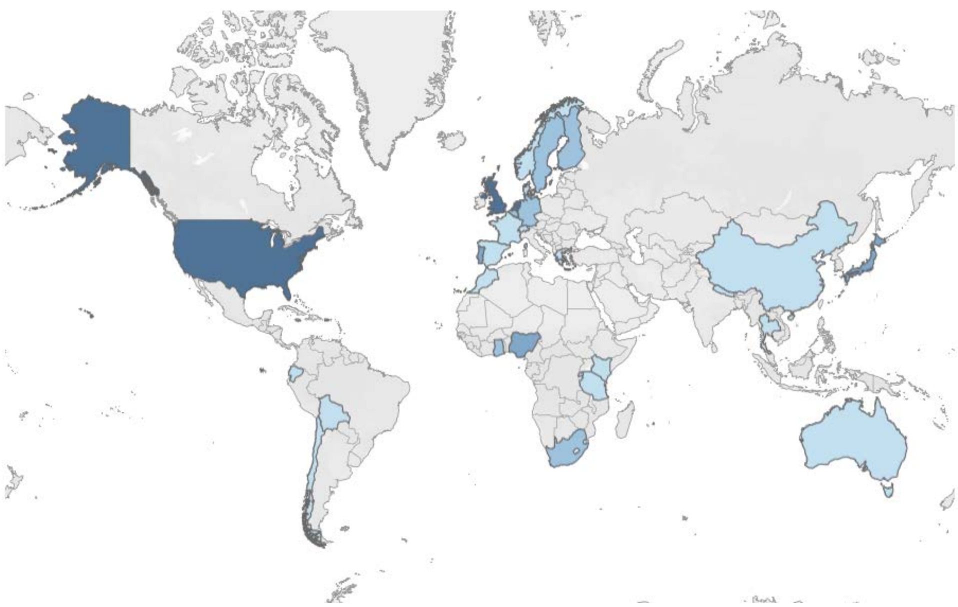

Fig. S1. Measurement locations of the IAEA DLW Database. Darker shading indicates a larger sample size from that country. Data were divided by country on the basis of the world bank coding classification.

Water turnover, body composition, and energy expenditure

Water turnover, energy expenditure, and body composition were measured using the DLW method (*33*). Details of the methods have been described in previous papers (*13, 34*). Briefly, each participant was given a drink that containing a weighed premixed dose of ^2H_2O and $H_2{}^{18}O$ (DLW) based on body size. Predose and postdose samples of urine, blood or salvia were collected and analyzed mostly by isotope-ratio mass spectrometry, with some samples analysed by laser spectroscopy. There is no significant effect of the analysis method on the estimated isotope enrichments (*35-37*). The dilution spaces of ^2H and ^{18}O (N_D and N_O, respectively) and the elimination rates of ^2H and ^{18}O (k_D and k_O, respectively) were obtained. Total body water was calculated from the average of the two dilution spaces, $N_D/1.043$ and $N_O/1.007$, which corrects for isotopic sequestration in non-aqueous tissues (*3, 41-43*). FFM was calculated by assuming a hydration coefficient of 73.2% in adults. Age-specific hydration coefficients were applied to children. The carbon dioxide production rate (rCO_2) was calculated using a common equation across all studies, specifically equation 1 from Speakman *et al.* (2021) (*13*). TEE was calculated using Wier's equation (equation 5 in reference 13, Speakman et al. 2021), using respiratory quotients for each specific study.

For n = 1439 subjects we also had measures of basal energy expenditure (BEE: n = 181 females and n = 621 males). Because only ~30% of subjects had measured BEE, the predicted BEE was used in this study with the Mifflin *et al*. equation for adults aged 18 years and older (*38*) and Schofield equation for those under 18 years old (*39*). The physical activity level (PAL) was calculated as TEE divided by BEE

The rate of daily water turnover (rH_2O, L/d) was calculated using the following equation(*40*):

$$rH_2O = k_D N_D \qquad [1]$$

When body water is maintained constant, rH_2O is equal to the total water efflux and total water influx (*41*).

Ambient temperature and other weather related variables

Weather related data were extracted differently for locations within and outside the USA. For measurements inside the USA, we used the National Centers for Environmental Information (NCEI)'s FTP site (ftp://ftp.ncdc.noaa.gov/pub/data/daily-grids/). This dataset contains averages of daily maximum, minimum, and average temperature (TMAX, TMIN, and TAVG) and precipitation (PRCP) for the contiguous USA between January 1, 1951, and the present (46). These data cover gridded fields that cover the land area between 24°N and 49°N and between 67°W and 125°W. The grids are approximately 4 km square. These data are compiled into averages for US counties. For each DLW measurement we used the known geographical location to identify the county where the person was measured and then extracted the daily averages for the duration of the measurement, which was also provided from the IAEA DLW database. We then generated an average maximum, minimum and mean temperature and precipitation exposure for each individual measurement.

For data outside the USA we matched the individual estimates for each study participant, based on reported dates and locations for each measurement in the database, to the local average ambient temperature (TAVG), relative humidity (RH), precipitation (PRCP) and windspeed (WDSP) extracted from the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information (NCEI) online data repository and NOAA's Global Surface Summary of the Day (GSOD; https://www.ncei.noaa.gov/metadata/geoportal/rest/metadata/item/gov.noaa.ncdc:C00516/html) records using the R package GSODR. The GSOD is derived from The Integrated Surface Hourly (ISH) dataset available from National Centers for Environmental Information. This database contains global averages of daily weather elements between 1929 and the present calculated on an hourly basis. For each participant, daily weather data were extracted from the database from the nearest weather station within a 50km radius of the study coordinates for the days of each DLW measurement and then averaged across those days.

Statistical analyses

We used the base package in R version 4.0.2 (R Core Team 2020-06-22) with RStudio version 1.2.5019 (2019-10-24) for all analyses. The mean and standard deviation (SD) were calculated for descriptive statistics. General linear models were implemented using the lm function for multiple regression analysis with WT as the dependent variable. Pearson correlation coefficients were calculated between log-transformed WT and log-transformed FFM, percent body fat, log-transformed TEE, PAL, or air temperature. Scatter plots were generated using the ggplot function with generalized additive models with integrated smoothness.

Table S1-1. Distribution of Observations by Economy & Country

Low HDI*		**259**
Ghana	GHA	59
Kenya	KEN	35
Nigeria	NGA	116
Tanzania	TZA	49
Middle HDI		**368**
China	CHN	16
Ecuador	ECU	44
Jamaica	JAM	72
Morocco	MAR	22
Mauritius	MUS	51
Seychelles	SYC	72
South Africa	ZAF	91
High HDI		**4977**
Belgium	BEL	50
Denmark	DNK	27
Finland	FIN	48
France	FRA	6
Germany	DEU	79
Great Britain	GBR	163
Japan	JPN	159
Netherlands	NLD	415
Norway	NOR	26
Spain	ESP	31
Sweden	SWE	97
United States	USA	3876
Total		**5604**

*HDI, human development index.

Table S1-2. Distribution of Observations by Country in Adults Aged 60 Years and Older

Tanzania	TZA	8
Germany	DEU	10
Japan	JPN	159
Netherlands	NLD	50
Norway	NOR	2
Sweden	SWE	49
United States	USA	1579
Total		**1857**

Table S1-3. Distribution of Observations by Country in People Aged <18 Years

Kenya	KEN	27
Nigeria	NGA	6
Ecuador	ECU	44
Morocco	MAR	22
Mauritius	MUS	51
Belgium	BEL	31
Denmark	DNK	27
Great Britain	GBR	111
Netherlands	NLD	95
Spain	ESP	31
Sweden	SWE	30
United States	USA	651
Total		**1126**

Male		Age (y)		Height (cm)		Weight (kg)		BMI		Fat (%)		FFM (kg)		TEE (MJ/d)		TBW (kg)		TBW (%)		WT (L/d)		WT/TEE (mL/kcal)	
Age group	N	mean	sd	mean	Sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
(0,0.5]	78	0.2	0.1	59.6	5.9	6.0	1.7	16.3	2.2	23.9	7.8	4.4	1.1	1.8	0.6	3.6	0.8	61.1	6.4	0.9	0.2	2.29	0.67
(0.5,1]	15	0.7	0.2	69.7	3.8	8.4	0.8	17.4	1.0	30.4	7.5	5.9	0.9	2.6	0.8	4.7	0.7	55.3	5.9	1.2	0.4	1.89	0.43
(1,2]	6	1.0	0.0	75.7	2.5	9.8	0.7	17.1	0.9	26.7	6.3	7.2	0.6	3.5	0.8	5.7	0.5	58.0	4.9	1.2	0.2	1.49	0.21
(2,4]	25	3.6	0.3	102.3	7.2	17.7	3.4	16.9	3.1	27.5	5.8	12.7	1.9	5.1	1.0	9.8	1.4	56.1	4.5	1.4	0.4	1.15	0.47
(4,6]	91	5.1	0.7	112.9	7.8	21.6	5.7	16.8	2.8	25.5	7.3	15.8	2.8	6.3	1.1	12.1	2.2	57.2	5.6	1.6	0.6	1.07	0.27
(6,8]	30	7.2	0.6	124.9	8.4	25.4	6.0	16.2	2.6	22.5	8.9	19.3	2.7	7.2	1.1	14.7	2.0	59.0	6.8	2.0	0.6	1.13	0.29
(8,10]	67	9.1	0.5	136.4	9.6	34.6	13.1	18.1	4.6	26.0	12.8	24.3	5.7	8.4	1.6	18.4	4.3	56.0	9.7	2.2	0.7	1.09	0.28
(10,12]	29	11.0	0.5	143.7	9.6	44.5	13.2	21.2	4.4	30.9	10.5	29.8	6.3	9.4	1.8	22.4	4.7	52.0	7.9	2.5	0.7	1.10	0.26
(12,16]	119	14.5	1.2	168.7	12.0	60.6	17.8	21.0	5.2	22.2	9.1	46.2	11.0	12.0	2.3	34.5	8.2	58.1	6.8	3.2	0.9	1.11	0.27
(16,20]	93	18.3	1.1	178.2	7.1	73.7	15.1	23.1	4.2	21.7	9.2	56.7	7.2	14.0	2.5	41.8	5.2	57.8	6.8	3.8	1.1	1.15	0.33
(20,25]	100	23.5	1.4	177.7	9.5	76.0	19.3	23.9	5.0	19.5	8.9	60.1	10.8	13.7	3.6	44.0	7.9	59.0	6.5	4.2	1.1	1.35	0.46
(25,30]	145	28.0	1.4	177.2	8.8	77.7	15.6	24.6	4.0	22.4	8.1	59.5	9.4	12.7	3.2	43.6	6.9	56.9	5.9	4.1	1.2	1.40	0.41
(30,35]	103	32.8	1.4	176.8	8.0	79.7	19.5	25.4	5.3	24.1	8.1	59.5	10.6	12.7	3.6	43.6	7.7	55.6	5.9	4.3	1.3	1.45	0.50
(35,40]	135	38.0	1.5	177.0	7.7	83.0	19.8	26.4	5.5	27.6	8.1	59.0	10.4	12.8	2.9	43.2	7.6	53.0	6.0	4.0	1.1	1.35	0.46
(40,45]	155	42.9	1.4	176.4	7.7	82.5	16.1	26.4	4.3	27.7	7.8	58.8	9.1	12.6	2.3	43.1	6.6	52.9	5.7	4.0	1.2	1.33	0.38
(45,50]	129	47.8	1.5	176.8	7.1	85.8	15.1	27.4	4.3	29.1	6.2	60.2	7.8	12.7	2.3	44.1	5.7	51.9	4.6	3.9	1.0	1.31	0.31
(50,55]	87	52.5	1.5	177.3	6.5	89.9	15.7	28.6	4.8	32.3	6.0	60.3	7.9	12.6	1.9	44.2	5.7	49.6	4.4	3.5	0.8	1.18	0.21
(55,60]	64	57.7	1.4	177.4	7.5	89.1	14.0	28.2	3.8	30.9	6.6	61.0	7.2	12.7	2.0	44.6	5.3	50.6	4.8	3.7	0.7	1.23	0.22
(60,65]	70	63.1	1.6	174.8	7.8	84.8	17.4	27.6	4.6	31.2	7.2	57.4	8.1	11.9	2.0	42.0	5.9	50.4	5.3	3.4	0.7	1.21	0.24
(65,70]	71	67.8	1.2	171.4	6.9	78.1	17.3	26.4	4.8	31.2	6.7	52.9	8.4	10.8	1.8	38.7	6.2	50.4	4.9	3.5	0.8	1.35	0.26
(70,80]	194	75.5	3.0	171.0	8.3	77.3	15.8	26.3	4.5	31.4	6.5	52.4	8.3	10.1	1.8	38.4	6.1	50.3	4.7	3.1	0.6	1.30	0.28
(80,90]	61	84.2	2.5	168.1	7.4	72.3	13.9	25.5	4.4	32.8	6.3	48.0	7.3	8.6	1.7	35.2	5.3	49.2	4.6	2.5	0.7	1.23	0.27
(90,100]	8	94.0	1.9	168.8	3.0	62.6	9.5	22.0	3.4	26.8	8.9	45.2	4.9	7.6	1.0	33.1	3.6	53.6	6.5	2.0	0.3	1.12	0.36
Female	N	mean	sd	mean	Sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
(0,0.5]	78	0.2	0.1	59.2	5.3	5.7	1.4	15.9	1.7	26.4	7.6	4.1	0.9	1.7	0.5	3.3	0.7	59.0	6.2	0.8	0.2	2.21	0.67
(0.5,1]	12	0.6	0.2	67.5	4.3	8.4	1.6	18.4	1.9	33.6	5.2	5.6	0.9	2.4	0.3	4.4	0.7	52.8	4.1	1.1	0.2	1.86	0.33
(1,2]	6	1.5	0.5	80.7	5.8	11.0	1.9	16.7	0.6	22.6	8.0	8.5	1.9	3.8	0.7	6.7	1.4	60.9	6.2	1.3	0.3	1.40	0.16
(2,4]	29	3.6	0.3	101.0	5.7	16.0	3.1	15.6	1.7	27.7	4.8	11.5	1.7	4.8	0.6	8.9	1.3	55.9	3.7	1.2	0.2	1.07	0.23
(4,6]	73	5.1	0.6	111.2	6.8	19.7	3.3	15.8	1.7	27.3	5.8	14.2	2.2	5.5	0.8	10.9	1.6	55.8	4.4	1.4	0.4	1.04	0.21
(6,8]	36	7.0	0.6	121.7	9.2	26.8	7.8	17.8	3.8	30.2	10.1	18.1	3.5	6.5	1.2	13.8	2.7	53.2	7.7	1.7	0.6	1.11	0.32
(8,10]	72	9.1	0.5	133.5	9.3	33.0	11.2	18.2	4.5	31.1	10.8	21.9	4.7	7.3	1.7	16.6	3.6	52.1	8.2	1.9	0.7	1.10	0.30
(10,12]	69	11.1	0.6	148.5	8.0	45.1	11.6	20.3	4.1	29.5	10.2	31.1	6.2	8.9	1.9	23.4	4.6	53.1	7.7	2.3	0.6	1.12	0.39
(12,16]	218	14.4	1.2	160.8	7.9	56.5	14.0	21.7	4.6	30.1	8.2	38.7	6.9	10.0	2.3	28.9	5.1	52.3	6.2	2.5	0.9	1.07	0.47
(16,20]	195	18.3	1.0	164.2	7.1	63.9	15.2	23.6	5.3	32.6	8.2	42.2	7.0	10.0	1.9	31.2	5.2	49.8	6.0	2.9	0.8	1.22	0.31
(20,25]	220	23.3	1.4	164.7	7.4	68.1	18.6	25.1	6.6	34.2	9.5	43.4	7.2	9.5	1.9	31.8	5.3	48.2	6.9	3.0	0.9	1.34	0.36
(25,30]	252	27.7	1.5	164.0	6.9	68.4	17.0	25.4	6.0	34.9	9.5	43.3	7.0	9.5	1.9	31.7	5.1	47.7	7.0	3.2	1.1	1.41	0.47
(30,35]	206	32.9	1.3	164.6	6.2	73.5	17.5	27.1	6.2	36.9	8.8	45.2	6.5	9.8	1.6	33.1	4.8	46.2	6.5	3.4	1.0	1.47	0.45
(35,40]	213	38.0	1.5	164.0	6.6	74.7	17.7	27.8	6.6	38.4	7.7	45.0	6.6	9.8	1.7	32.9	4.8	45.1	5.6	3.2	0.8	1.39	0.35
(40,45]	275	42.8	1.4	163.7	7.2	73.4	18.7	27.3	6.3	37.9	8.0	44.5	7.6	9.8	1.9	32.6	5.6	45.5	5.8	3.3	0.9	1.44	0.43
(45,50]	159	47.4	1.5	164.5	6.1	73.8	17.0	27.3	6.2	38.7	7.9	44.2	6.2	9.8	1.5	32.4	4.5	44.9	5.8	3.2	0.9	1.37	0.38
(50,55]	102	52.8	1.5	163.4	5.9	79.6	19.5	29.8	7.0	42.2	7.8	44.7	6.6	9.7	1.6	32.7	4.8	42.3	5.7	3.1	0.9	1.35	0.37
(55,60]	99	58.3	1.5	164.0	6.0	76.7	17.0	28.4	5.7	41.7	7.5	43.7	6.1	9.7	1.5	32.0	4.5	42.7	5.5	3.3	0.7	1.42	0.32
(60,65]	239	63.3	1.5	161.5	7.2	76.9	18.4	29.5	6.9	42.7	6.6	43.1	6.8	9.3	1.6	31.6	5.0	42.0	4.8	3.2	0.7	1.47	0.37
(65,70]	361	68.1	1.5	161.3	6.8	74.0	15.8	28.4	5.7	41.8	7.3	42.3	5.9	9.0	1.3	31.0	4.4	42.7	5.3	3.1	0.7	1.44	0.31
(70,80]	653	75.0	2.8	159.4	6.8	68.7	14.4	27.0	5.2	41.1	6.7	39.7	5.6	8.2	1.3	29.1	4.1	43.1	4.9	2.8	0.7	1.43	0.34
(80,90]	140	83.6	2.4	157.4	7.3	64.1	12.4	25.9	4.7	39.5	6.5	38.2	5.2	7.4	1.4	28.0	3.8	44.3	4.8	2.4	0.6	1.39	0.31
(90,100]	22	94.4	1.8	158.0	9.1	59.0	12.8	23.5	4.1	34.6	7.9	38.3	8.5	6.2	1.2	28.0	6.2	47.9	5.8	2.0	0.4	1.39	0.26

Table S2. Key characteristics by age-sex group (mean and SD). BMI, body mass index; Fat, percent body fat; FFM, fat-free mass; TEE, total energy expenditure; TBW, total body water; WT, water turnover.

Table S3. Multiple regression analysis to predict water turnover in adults aged 18 years and older.

	β	std. err.	t-value	p	
(Intercept)	-0.059	0.036	-1.635	0.102	
Age (yr)	-0.203	0.051	-3.982	0.00007	***
Height (cm)	0.003	0.047	0.064	0.949	
FFM (kg)	0.454	0.076	5.947	0.00000	***
% body fat (%)	0.050	0.049	1.020	0.308	
Sex (F=0, M=1)	0.075	0.045	1.691	0.091	
TEE (MJ/d)	-0.094	0.128	-0.734	0.463	
PAL	0.309	0.083	3.725	0.0002	***
Air temp. (°C)	0.240	0.035	6.887	0.00000	***
Relative humidity (%)	0.093	0.030	3.137	0.0018	**
Wind speed (m/s)	-0.027	0.025	-1.067	0.286	
precipitation (mm)	0.018	0.027	0.655	0.513	
HDI (H=0, M=1, L=2)	0.158	0.028	5.678	0.00000	***
Effective latitude (°)	0.038	0.024	1.544	0.123	
Altitude (m)	0.062	0.025	2.448	0.0145	*
	SEE	R2	adj R2	P	
	0.7944	0.456	0.4496	< 2.2e-16	

FFM, fat-free mass; TEE, total energy expenditure; PAL, physical activity level; HDI, Human Development Index. * P<0.05, ** P<0.01, *** P<0.001

Table S4. Multiple regression analysis including first and second-order terms to predict water turnover (WT) in adults aged 18 years and older.

	β	std. err.	t-value	p	
(Intercept)	0.032	0.032	0.987	0.32389	
PAL	0.237	0.019	12.307	0.00000	***
FFM (kg)	0.386	0.031	12.348	0.00000	***
Sex (F=0, M=1)	0.018	0.026	0.701	0.48348	
Air temp. (°C)	-0.192	0.063	-3.048	0.00236	**
Air temp. * Air temp	0.479	0.065	7.339	0.00000	***
Relative humidity (%)	0.067	0.028	2.399	0.01660	*
Athlete (No=0, Athlete=1)	0.041	0.012	3.357	0.00081	***
HDI (H=0, M=1, L=2)	0.052	0.025	2.051	0.04044	*
Altitude (m)	0.133	0.025	5.443	0.00000	***
Age (year)	0.611	0.123	4.986	0.00000	***
Age * Age	-0.800	0.125	-6.401	0.00000	***
	SEE	R2	adj R2	P	
	0.7618	0.486	0.484	< 2.2e-16	

The positive coefficient of Air temp.^{2} indicated an U-shaped relationship between water turnover and air temp.. The negative coefficient of Age^2 indicated an inverse U-shaped relationship between water turnover and age. Eleven subjects who engaged in the DLW experiment at an altitude over 3000 m were excluded from the analysis (7490 m [n = 3], 5390 m [n = 6], and 3263 m [n = 2]).

Table S5. Participant characteristics by Athletic status & Sex (mean ± SD; [range])*

	Male		Female	
	Athlete (n = 95)	Non-athlete (n = 720)	Athlete (n = 19)	Non-athlete (n = 1100)
Age (y)	23.5 ± 5	38.1 ± 12.1	24.8 ± 5.6	35.5 ± 12.1
	[18-45]	[18-59]	[18-36]	[18-59]
Height (cm)	183.2 ± 10	178.6 ± 7.1	173.1 ± 11.4	164.7 ± 6.5
	[155-204.7]	[153-204]	[162.4-195]	[142.1-186]
Weight (kg)	78.2 ± 12.3	85.9 ± 18.8	66.5 ± 11.4	79.5 ± 23.6
	[51.8-108.9]	[49.9-189.9]	[52.2-84.3]	[38.3-192.4]
BMI (kg/m^2)	23.2 ± 2.3	26.9 ± 5.7	22.0 ± 1.7	29.3 ± 8.5
	[18.9-29.9]	[15.7-61.4]	[19.6-25.0]	[12.5-71.9]
Fat (%)	17.4 ± 5.4	27.3 ± 9.1	28.9 ± 8	38.5 ± 9.3
	[3.2-40.4]	[3.4-56.2]	[9.8-40.0]	[6.9-70.1]
FFM (kg)	64.7 ± 11.2	61.3 ± 8.8	46.7 ± 5.6	47.2 ± 9.0
	[38.3-96.9]	[36.3-97.8]	[35.7-56.2]	[26.3-89.8]
TEE (MJ/d)	17.3 ± 3.3	13.6 ± 2.8	12.8 ± 1.9	10.2 ± 1.9
	[7.7-26.3]	[6.7-26.1]	[10.2-17.1]	[4.7-19.9]
WT (L/d)	5.1 ± 1.6	3.9 ± 1.1	4.1 ± 1.5	3.2 ± 0.9
	[1.8-10.6]	[1.7-10.1]	[1.8-8.0]	[1.3-8.6]
WT/Weight (L/kg/d)	66.2 ± 21.1	47.1 ± 14.6	61.7 ± 19.8	43.0 ± 16.8
	[26.9-141.0]	[17.9-139.2]	[29.6-100.9]	[10.5-194.8]

*BMI, body mass index; FFM, fat-free mass; TEE, total energy expenditure; WT, water turnover.

Table S6. Participant characteristics by Occupation & Sex (mean ± SD; [range])*

	Male			Female			
	C (n = 589)	HG (n = 21)	HGF (n = 19)	C (n = 809)	HG (n = 19)	HGF (n = 22)	SA (n = 7)
Age (y)	38.4 ± 12.3 [18-59]	32.2 ± 12.3 [18-58]	41.1 ± 10.7 [18-54]	37.3 ± 11.7 [18-59]	32.8 ± 12.1 [18-59]	40 ± 12.8 [18-57]	30 ± 6.4 [21-38]
Height (cm)	178.5 ± 7.3 [153.0-204.0]	159.6 ± 7.2 [144.5-171.1]	165 ± 5.6 [155.2-178.1]	164.3 ± 6.8 [142.1-186]	149.7 ± 8 [137.4-164.5]	150.2 ± 5 [141.5-160.6]	161.1 ± 7.8 [152-177.5]
Weight (kg)	85.5 ± 18.7 [49.9-189.9]	51.5 ± 4.8 [42.8-58.2]	69.1 ± 9.6 [53.8-84.9]	80.8 ± 24.6 [38.3-192.4]	45.5 ± 6.4 [34-55]	54.9 ± 7.7 [42.8-66.5]	59.6 ± 5.5 [51.3-65.4]
BMI (kg/m^2)	26.8 ± 5.6 [15.7-61.4]	20.2 ± 1.7 [18.1-23.8]	25.3 ± 2.7 [20.6-31.1]	29.9 ± 8.9 [12.5-71.9]	20.2 ± 2 [16.7-23.9]	24.3 ± 2.8 [19.9-29]	23.1 ± 2.7 [20-26.2]
Fat (%)	27.7 ± 9.2 [3.4-56.2]	14.0 ± 5.5 [2.2-23.9]	21.5 ± 7.6 [12.4-42.3]	39.0 ± 9.5 [6.9-70.1]	23.1 ± 5 [13.3-31.9]	29.1 ± 6.1 [15.5-40.6]	30.7 ± 5.7 [22.4-38.2]
FFM (kg)	60.6 ± 8.5 [36.3-92.3]	44.2 ± 3.9 [34.8-52.2]	54.2 ± 8.8 [41.1-73.1]	47.5 ± 9.5 [26.3-89.8]	34.8 ± 4.1 [29.5-43.6]	38.8 ± 4.8 [26.2-46]	41.2 ± 4.0 [35.5-45.3]
TEE (MJ/d)	13.8 ± 3.0 [6.7-26.1]	10.5 ± 1.6 [7.5-14.3]	14.1 ± 3.3 [8.2-20.8]	10.3 ± 2.0 [4.7-19.9]	8.0 ± 1.5 [6.1-12.0]	9.9 ± 1.3 [7.5-12.7]	13.9 ± 1.9 [10-15.8]
WT (L/d)	3.9 ± 1.1 [1.7-10.1]	4.5 ± 0.6 [3.4-5.9]	6.2 ± 2.3 [3.2-11.6]	3.3 ± 0.9 [1.3-8.6]	3.9 ± 0.6 [2.7-5]	3.6 ± 0.9 [1.5-5]	4.0 ± 0.3 [3.7-4.4]
WT/Weight (L/kg)	47.0 ± 15.0 [17.9-142.2]	89.4 ± 16.7 [64.7-134.9]	88.1 ± 24.7 [47.5-136.2]	43.8 ± 17.4 [10.5-194.8]	85.5 ± 12.2 [64.8-105.3]	66.9 ± 16.8 [27.6-102.2]	68.1 ± 3.6 [62.7-73.9]

*BMI, body mass index; FFM, fat-free mass; TEE, total energy expenditure; WT, water turnover; C, control; HG, hunter-gatherers; HGF, mixed farmer and hunter-gatherer; SA, subsistence agriculturalists.

Table S7. Participant characteristics by Human Development Index (HDI) & Sex (mean ± SD; [range])*

	Male			Female		
	High HDI (n = 813)	Middle HDI (n = 103)	Low HDI (n = 57)	High HDI (n = 1339)	Middle HDI (n = 148)	Low HDI (n = 161)
Age (y)	38.7 ± 11.4 [18-59]	32.8 ± 5.7 [21-44]	32.1 ± 9.7 [18-58]	36.3 ± 11.3 [18-59]	31.9 ± 6.5 [20-45]	32.1 ± 10.2 [18-59]
Height (cm)	178.5 ± 7.0 [153-204]	171.8 ± 6.6 [157-187]	165.8 ± 8.7 [144.5-182.8]	165 ± 6.4 [146-186]	162.3 ± 6.2 [147-183.3]	158.9 ± 7.1 [137.4-176.5]
Weight (kg)	85.1 ± 16.2 [49.9-174.6]	68.4 ± 14.4 [47.6-127]	57.1 ± 8 [41.6-74.7]	73.0 ± 17.4 [38.3-164.5]	76.1 ± 22.8 [36.9-148.2]	57.4 ± 12.3 [34-106.9]
BMI (kg/m^2)	26.7 ± 4.7 [15.7-57.1]	23.1 ± 4.3 [15.5-38.4]	20.7 ± 2.3 [16.7-26.4]	26.8 ± 6.2 [12.5-55.3]	28.8 ± 8.2 [14.5-54.8]	22.7 ± 4.7 [15.4-47.8]
Fat (%)	27.3 ± 8.1 [3.4-54.5]	22.6 ± 7.8 [1.3-44.1]	13.3 ± 5.8 [1.2-28]	37.4 ± 8.4 [8-70.1]	40.4 ± 9.2 [19.7-59.6]	29.4 ± 8.1 [5.5-51.8]
FFM (kg)	61.1 ± 8.6 [36.3-97.8]	52.3 ± 8.4 [33.9-77.9]	49.3 ± 6.3 [34.8-63.3]	44.6 ± 6.8 [26.3-95.7]	43.7 ± 8.5 [27.5-68.3]	39.8 ± 5.5 [29.5-66.4]
TEE (MJ/d)	13.3 ± 2.8 [6.7-34.3]	10.8 ± 2.3 [5.4-18.3]	11.9 ± 2.0 [7.5-15.4]	9.8 ± 1.7 [4.7-20.4]	9.3 ± 2.0 [4.6-15]	9.3 ± 1.6 [6.1-17.4]
WT (L/d)	3.9 ± 1.1 [1.7-10.1]	4.0 ± 1.2 [1.7-8.7]	5.2 ± 1.1 [3.3-8.0]	3.1 ± 0.9 [1.3-8.4]	3.2 ± 0.9 [1.3-6.6]	3.8 ± 0.9 [2.1-7.2]
WT/Weight (L/kg/d)	47.0 ± 13.5 [17.9-139.2]	59.6 ± 16.9 [24.8-142.2]	91.3 ± 17.5 [61-134.9]	44.5 ± 16.2 [14-194.8]	44.2 ± 12.0 [14.5-80.2]	67.0 ± 16.4 [36-114]

*BMI, body mass index; FFM, fat-free mass; TEE, total energy expenditure; WT, water turnover.

The IAEA DLW database group authorship (database version 3.5.3).

This group authorship contains the names of people whose data were contributed into the IAEA DLW database by the analysis laboratory but they later could not be traced, or they did not respond to emails to assent inclusion among the authorship. The list also includes some researchers who did not assent inclusion to the main authorship because they felt their contribution was not sufficient to merit authorship, or their specific data was not used in the present analysis (eg pediatric data)

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