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Original article

2024 Adult Compendium of Physical Activities: A third update of the energy costs of human activities

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Abstract

Background: The Compendium of Physical Activities was published in 1993 to improve the comparability of energy expenditure values assigned to self-reported physical activity (PA) across studies. The original version was updated in 2000, and again in 2011, and has been widely used to support PA research, practice, and public health guidelines.

Methods: This 2024 update was tailored for adults 19–59 years of age by removing data from those ≥60 years. Using a systematic review and supplementary searches, we identified new activities and their associated measured metabolic equivalent (MET) values (using indirect calorimetry) published since 2011. We replaced estimated METs with measured values when possible.

Results: We screened 32,173 abstracts and 1507 full-text papers and extracted 2356 PA energy expenditure values from 701 papers. We added 303 new PAs and adjusted 176 existing MET values and descriptions to reflect the addition of new data and removal of METs for older adults. We added a Major Heading (Video Games). The 2024 Adult Compendium includes 1114 PAs (912 with measured and 202 with estimated values) across 22 Major Headings.

Conclusion: This comprehensive update and refinement led to the creation of The 2024 Adult Compendium, which has utility across research, public health, education, and healthcare domains, as well as in the development of consumer health technologies. The new website with the complete lists of PAs and supporting resources is available at https://pacompendium.com.

Keywords: Adults; Energy expenditure; Exercise; MET; Physical Activities

1. Introduction

The Compendium of Physical Activities (Compendium) is a comprehensive list of metabolic equivalent (MET; standardized for resting metabolic rate (RMR) as 1 MET = 3.5 mL/kg/min) intensity values for physical activities (PAs) performed in various settings and is available in 8 languages.[1] *Prior to* the development of the Compendium, PA researchers assigned different energy expenditure (EE) values, frequently expressed in various different units, to a given PA listed on different self-report PA questionnaires,[2,3] which complicated efforts to describe dose–response associations between participation in PAs with different intensities and health outcomes, morbidity, and mortality.

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The Compendium provides a consistent MET value, based whenever possible on published studies of energy cost, for scoring PA questionnaires, allowing for improved comparability across studies.[4] The Compendium was initially developed in 1989 and first published in 1993.[4] Later updates in 2000[5] and 2011[6] expanded the number of Specific Activities included and provided transparency in measured and estimated MET values, encouraging researchers to fill gaps in measured PAs.[7,8]

The Compendium covers energy costs of individual PAs across PA and health studies, with updates extending to other areas, including personal health and fitness programming and individual PA assessment settings. Since its inception, the Compendium has been used widely to support PA and health research[9−11]and to anchor national and international PA guidelines.[12−14] It has also appeared in mobile technologies designed for exercise and weight management, and has been applied in educational settings as well as public health and health promotion settings.[15]

Since RMR changes across the lifespan (dramatically throughout adolescence[16,17]), a Youth Compendium of Physical Activities (Youth Compendium) was published for children 5−18 years old in 2008[18] and updated in 2017.[19] RMR is comparatively lower in older adults,[20,21] so in 2024, a Compendium for Older Adults ≥60 years was developed.[22] An additional 2024 iteration of the Compendium is limited to MET values for adults 19−59 years of age (Adult Compendium).

The 2024 Adult Compendium represents the most comprehensive update in this multi-year effort by building upon the original 1993 Compendium[4] and its subsequent 2000[5] and 2011[6] versions with primary objectives to (a) systematically review the literature to identify additional studies reporting the energy costs of PAs, (b) integrate new PAs and their associated MET values, and (c) continue to replace estimated MET values with measured MET values where available. The objectives described here provide the most comprehensive update to the Adult Compendium performed to date.

2. Methods

2.1. Search strategy

The review methodology was established *prior to* its initiation. A research librarian conducted a comprehensive, systematic search for articles and abstracts published since the 2011 Compendium update,[6] specifically from January 2011 through March 2023. Searches were conducted using 4 databases (PubMed, Embase, SPORTDiscus (EBSCOhost), and Scopus). The librarian conducted 22 separate searches using a unique set of keywords that paired the Major Heading activity concept from the Compendium (e.g., "Dancing" and "Music playing") with a variety of terms related to energy cost (e.g., EE, oxygen consumption, MET, and others) using the Boolean operator AND (see Supplementary Table 1 for additional details). Research team members also implemented additional direct literature search strategies in attempts to capture articles outside of the systematic review, and they contacted researchers to identify unpublished data (Todd Manini, personal communication, July 2023; Tabitha Craig, Ryan E. Rhodes, and Yoah Sui, personal communication, June 2023) or for additional details (e.g., participant weight, PA description, or unreported measured energy cost data) needed from published works.

2.2. Eligibility criteria

Articles were included if (a) data reported were from participants with a mean age of 19−59 years, (b) the assessed and reported energy cost of PA was measured using indirect or direct calorimetry, and (c) articles and abstracts were available in English. We excluded articles if (a) they only reported resting, peak, or maximal energy cost values, (b) participants had a disability restricting PA (e.g., amputee, spinal cord injury, used a wheelchair), (c) the estimated EE of PAs was from heart rate monitors, motion sensors, or prediction equations (e.g., Polar, SenseWear, ActiGraph accelerometer, or American College of Sports Medicine prediction equations), or (d) participants were described as pregnant or living with a chronic disease (e.g., chronic obstructive pulmonary disease, heart disease, cancer).

2.3. Study selection

Identified articles were exported to Endnote X9 (Clarivate, Philadelphia, PA, USA) for removal of duplicates and subsequently moved into Covidence systematic review software (Veritas Health Innovation, Melbourne, VIC, Australia; available at: www.covidence.org) for abstract screening and full-text review management. Two screening approaches were used to identify eligible abstracts. First, if the database searches identified <1000 articles for an individual search Major Heading (e.g., Music playing), 2 reviewers (SDH, EAW, TVB, MH, CLK, and/or JMS) independently screened all abstracts for eligibility and a third reviewer (SDH or EAW) resolved conflicts. If database searches identified ≥1000 articles (e.g., Walking), a 2-stage automation approach was used to prioritize the screening process using ICF's Document Classification and Topic Extraction Resource (DoCTER) (https://www.icf-docter.com/) to prioritize the abstracts. The Appendix describes the DoCTER abstract selection process. An overview of the Covidence systematic review study selection process is presented in Supplementary Table 2.

2.4. Data extraction

One reviewer (SDH, EAW, BEA, MH, or CLK) independently extracted participant age and EE data (e.g., METs, oxygen uptake (VO_2, mL/kg/min)) for identified PAs. A second reviewer (SDH, EAW, or MH) checked the extracted data for accuracy. Data from the 2011 Compendium and the 2024 search strategies were merged, sorted by Major Heading, Specific Activity codes, activity descriptions, and MET values, and then grouped into matching or new Specific Activity codes with associated activity descriptions created.

2.5. Calculation of MET values

METs reflect the ratio of a PA's energy cost in mL/kg/min relative to a standardized RMR of 3.5 mL/kg/min or approximately 1.0 kcal/kg/h. In 1960, Balke[23] identified a standardized RMR as 1 MET. This standard MET is used in the Compendium to allow for comparison of activity MET values between studies.[24] The Compendium classifies sedentary behaviors as 1.0−1.5 METs, light-intensity PAs as 1.6−2.9 METs, moderate-intensity PAs as 3.0−5.9 METs, and vigorous-intensity PAs as ≥6.0 METs, which are commonly used values in research and public health.[13,14]

Most reviewed studies presented PA energy cost data as mL/kg/min or a standard MET using 3.5 mL/kg/min as the denominator. However, others presented VO_2 data in various units, such as L/min and kcal/min, $\%VO_{2peak}$, METs/m, and relative METs, where the activity VO_2 was divided by a measured or estimated RMR in mL/kg/min. In these situations, the values were converted to standard METs. For example, L/min was divided by the study sample's body weight (kg) and multiplied by 1000 mL to calculate mL/kg/min. It was then divided by 3.5 mL/kg/min to obtain a standard MET. Additional equations used to convert EE values are available on the Compendium website.

2.6. Presentation of the 2024 Adult Compendium

Previous Compendium versions provided a detailed explanation of the coding scheme used.[4−6] The 2024 Adult Compendium maintains the same 5-digit coding scheme that contains Major Headings (first 2 digits) and Specific Activity codes (last 3 digits), followed by their associated standard MET value and activity description (Table 1). The activity descriptions provide quantitative details (e.g., bicycling pedal cadence, riding speed, and grade) and qualitative information (e.g., self-selected pace, general or perceived intensity level as light, moderate, and vigorous effort). Maintaining consistency with previous Compendium versions, in the 2024 Adult Compendium we rounded significant digits for MET values to 0, 3, 5, and 8. For example, a MET value of 4.45 is rounded to 4.5 and a MET value of 5.1 is rounded to 5.0.

3. Results

The systematic review identified 32,173 abstracts. After removing duplicates across search databases (n = 10,868 duplicates), 21,137 abstracts were available for screening and review. We reviewed 1507 full-text articles, resulting in 701 articles for data extraction. From these full-text articles, 2356 new PA EE values were incorporated into existing 5-digit Specific Activity codes or used to create new codes. A summary of the systematic review results is presented in Supplementary Table 2.

The 2024 Adult Compendium contains 22 Major Headings and 1114 Specific Activity codes (Table 2) and is available on a new website: https://pacompendium.com. In this update, 912 PAs (82 %) have measured MET values compared to 561 of the 821 PAs (68%) in the 2011 Compendium (Table 3). Estimated METs have been used when measured METs are unavailable for a Specific Activity (e.g., activities that are unmeasured or challenging to measure, such as surfing, diving, or wrestling), but they now comprise only 18.5% of the Adult Compendium. The website provides additional resources, including detailed lists of MET conversion processes and PA descriptions, a complete guide for tracking changes with each Compendium version (1993, 2000, 2011, and 2024), language translation instructions, and other resources. We identify Specific Activity codes with measured (e.g., published EE/MET data from articles referenced in this update) and estimated MET values in the website data tables, with citations

Table 1
Example of the 2024 Adult Compendium organizational scheme.

5-Digit code	Major Heading (code)	MET intensity	Activity description (Specific activities code)
05010	Home activities (05)	3.3	Cleaning, sweeping carpet or floors, general (010)
11004	Occupation (11)	2.8	Active workstation, treadmill desk, walking 1.0−2.0 mph (004)
16050	Transportation (16)	6.8	E-bike (electrically assisted) for transportation (050)
18225	Water activities (18)	2.8	Stand up paddleboard, standing, 10−19 strokes/min (225)

Abbreviation: MET = metabolic equivalent.

Table 2
Major Headings and Specific Activity codes in the 2024 Adult Compendium.

Major Heading number − Name (Total number of Specific Activity codes)		
01 − Bicycling (44)	09 − Miscellaneous (28)	17 − Walking (93)
02 − Conditioning exercises (86)	10 − Music playing (22)	18 − Water activities (87)
03 − Dancing (28)	11 − Occupation (149)	19 − Winter activities (52)
04 − Fishing and hunting (37)	12 − Running (66)	20 − Religious activities (24)
05 − Home activities (78)	13 − Self-care (11)	21 − Volunteer activities (19)
06 − Home repair (37)	14 − Sexual activity (3)	22 − Video games (8)
07 − Inactivity (17)	15 − Sports (158)	
08 − Lawn and garden (54)	16 − Transportation (12)	

Table 3
Compendium versions.

Version	Publication year	Referred to as	Major Headings (#)	Total Specific Activities (measured/estimated)
1	1993	Compendium	19	477
2	2000	Compendium	21	605
3	2011	Compendium	21	821 (561/260)
4	2024	Adult Compendium	22	1114 (912/202)

for all studies included. An overview of the Compendium versions and related changes is presented in Table 3.

Incorporating data from the systematic review added 303 new Specific Activity codes with measured METs (Table 4). These PAs added additional details to existing PAs (e.g., stand-up paddle boarding *at multiple speeds*), reflected trends in emergent technology (e.g., virtual reality exercise such as Supernatural flow and boxing activities (Tabitha Craig, Ryan E. Rhodes, and Yoah Sui, personal communication, June 2023)), and added new PAs not in previous Compendia versions (e.g., frisbee golf, futsal, walking backward, E-bike (electrically assisted), race walking).

The 2024 Adult Compendium provides 176 changes to MET values or Specific Activity descriptions from the 2011 Compendium. We made some changes in MET values to reflect measured values in previously estimated Specific Activity codes (e.g., 12060 – Running, 6.7 mph), updated others to reflect additional available data (e.g., 10110 Woodwind instruments, sitting changed from 2.0 to 1.8 METs), or to improve a Specific Activity description (e.g., to differentiate specific occupational tasks, we removed computer work from code 11580 and created a new code: 11582 – Sitting, computer work). We also moved some codes to a different Major Heading to better group the Specific Activity code with others similar PAs. For example, aerobic step exercise (codes 03015–03022) was moved from the Major Heading Dancing to Conditioning exercises. Further, we added a new Major Heading "Video games" to capture the expanse of research in this area. We identified 67 articles that reported over 200 PAs combined into 8 Specific Activity codes.

4. Discussion

The Compendium has maintained relevance for over 30 years, partly due to its evolution as a living document with an expanded and enhanced Specific Activity code list. The first update, published in 2000, included ~10 years of new data and added 2 Major Headings (Religious activities and Volunteer activities).[5] The second update, published in 2011, added over 200 new Specific activities codes and differentiated between measured MET values supported by published research (68% in 2011) and estimated MET values.[6] The 2011 Compendium was the first version supported by a website that contained the current Compendium; a tracking document of MET values from 1993, 2000, and 2011 versions; and references for measured PAs. For the 2024 revision, we added Adult to the Compendium and limited it to 19–59 years of age to differentiate it from the Youth Compendium (ages 6–18)[19] and the Older Adult Compendium (≥60 years of age).[22] Collectively, the Youth Compendium,[19] Adult Compendium, and Older Adult Compendium[22] provide MET values for PAs across the lifespan. We included new Specific Activity codes and their associated MET values by conducting a comprehensive literature search and added them to the 2024 Adult Compendium. We also replaced some estimated MET values in the 2011 Compendium with measured values and transferred METs for adults ≥60 years old to the Older Adult Compendium. This intentional separation allows a focused Older Adult Compendium to better reflect this age group's distinctive RMR characteristics. We added 303 new Specific Activity codes and modified 176 by increasing or decreasing existing MET values based on new energy cost data or modifying activity descriptions. We added 1 new Major Heading (Video games). We continue to provide an online presence with a new website for transparency and use.

4.1. Utility

Our goal is that the 2024 Adult Compendium will continue to be a reference for research, public health, and classification

Table 4
New Specific Activity codes added by Major Heading.

Major Heading number – Name (New Specific Activity codes)		
01 – Bicycling (23)	09 – Miscellaneous (2)	17 – Walking (42)
02 – Conditioning exercises (35)	10 – Music playing (2)	18 – Water activities (33)
03 – Dancing (18)	11 – Occupation (29)	19 – Winter activities (22)
04 – Fishing and hunting (5)	12 – Running (42)	20 – Religious activities (0)
05 – Home activities (3)	13 – Self-care (0)	21 – Volunteer activities (0)
06 – Home repair (0)	14 – Sexual activity (0)	22 – Video games (8)
07 – Inactivity (1)	15 – Sports (33)	
08 – Lawn and garden (2)	16 – Transportation (3)	

of PA intensity categories and be helpful in various educational settings. To maintain continuity with previous work, we present standard MET values in the 2024 Adult Compendium.

MET-minutes and MET-hours are often used to assess PA dose with various health outcomes.[25] These values are computed by multiplying the Specific Activity MET value by the duration of the reported PA in minutes or hours. For example, riding an E-bike with light electronic support for 30 min (code 01084; 6.0 METs) results in 180 MET-minutes (6.0 METs × 30 min) or 3 MET-hours (6.0 METs × 0.5 h). The 2018 U.S. PA Guidelines recommend 150−300 min/week of moderate-intensity PA, 75 min/week of vigorous-intensity PA, or a combination of both. This volume of PA is equivalent to ∼500−1000 MET-min/week, which is sufficient to reduce the risks of morbidity and mortality.[26]

4.2. New Major Heading

Similar to the 2000 Compendium,[5] where 2 Major Headings were added, we added a new Major Heading, Video games, in this third update. The need for this additional grouping is based on significant research over the last 15 years that has evaluated a range of video games, from traditional seated handheld controller games[27] to interactive gaming requiring upper body[28] and lower body movement.[29] Additionally, significant variation in EE is observed within a game based on the difficulty level, the player's experience, and the effort involved. For example, Nintendo Wii boxing ranges from 2.5 METs during free play[30] to over 8.0 METs for vigorous play using an Xbox 360.[28] For these reasons, we grouped video game data into Specific Activity codes based on intensity and type of gameplay in the new Major Heading, which differs from primarily alphabetizing Specific Activity codes in other Major Headings. The associated activity description provides additional context to help identify the most appropriate intensity level. For example, traditional seated handheld controller games are in the new code 22040 (seated, video game, handheld controller; 1.3 METs). Games with increased effort and complexity and body motion sensing games are assigned Specific Activity code 22200 (active video game, motion sensing game/using upper-body, light-to-moderate effort; 3.0 METs) or Specific Activity code 22360 (conditioning/exercise virtual reality fitness, vigorous-intensity; 9.8 METs).[31]

Ongoing developments in PA assessment research since the last 2011 Compendium update include additional focus on multiple behaviors (i.e., PA and sedentary behaviors)[32,33] using self-report,[34] mHealth technologies,[35] and device-based measures, such as accelerometers.[36] The 2024 Adult Compendium supports these efforts by expanding the range of available Specific Activity codes for sedentary behaviors and PAs, which can be used to quantify PA from self-report methods and provide context to device-based measures. Combining questionnaires and device-based measures[33] may support public health efforts to further quantify the dose-response of PA and sedentary behaviors for health outcomes, potentially leading to new device-based guidelines for PA and health and guidance for reducing sedentary time throughout the day.[14,37]

4.3. Relative EE and absolute EE

Though the original purpose of the Compendium was to support epidemiological research in the assignment of MET values and to improve comparability across studies, many users have attempted to use the Compendium to calculate individual EE estimates and develop exercise prescriptions in clinical settings. Several factors can influence RMR and the EE of PA;[38−40] thus, the Compendium can serve as a starting point for prescribing individual activities but does not reflect precise individual EE values. For example, Browning et al.[41] reported significantly higher EE (∼8%−15%) in women with obesity (age = 28.5 ± 7.6 years; body mass index = 33.9 ± 3.6 kg/m^2) compared to women without obesity (age = 22.8 ± 3.6 years; body mass index = 21.6 ± 2.0 kg/m^2) across multiple treadmill speeds and grades. EE may still be categorized in the same general intensity level (i.e., light intensity) but may not reflect an individual's more precisely measured EE. Studies consistently note differences in RMR based on age, sex, height, and body weight or body composition and recommend accounting for these factors to estimate RMR when measured RMR values are unavailable to use as the denominator in computing METs (i.e., relative METs).[38,39,42] Kozey et al.[43] have proposed a corrected MET to adjust for individual differences in RMR using the Harris-Benedict RMR equation.[38] This adjustment modifies the standard MET to reflect the individual variation in age, sex, height, and body weight. Due to the variation in RMR between individuals, relative, standard, and corrected METs understandably differ.

4.4. Strengths and limitations

The continued commitment to expanding its evidentiary basis has produced the most comprehensive update to the 2024 Adult Compendium. Data from over 2000 PAs were identified and included to expand Specific Activity codes, add a new Major Heading, and reduce the frequency of estimated values from 260 in the 2011 update to 207 in this current update.

Categorizing the energy costs of water PAs like surfing and scuba diving or during live sports activities such as boxing, American football, and other team sports continues to be a challenge due to the inherent limitations of existing measurement strategies. As with prior versions of the Compendium, the 2024 Adult Compendium is intended for use in non-disabled adults and adults without significant health conditions that affect EE or metabolism (e.g., heart failure patients, patients with chronic obstructive pulmonary disease, pregnant women, adults with Down Syndrome). By creating an Older Adult Compendium for those ≥60 years of age,[22] the 2024 Compendium is limited to adults 19−59 years of age.

5. Conclusion

For over 30 years, the Compendium has set a global standard used to identify the EE cost of Specific Activity codes

ranging from sedentary behaviors to an abundance of PA variations. The 2024 Adult Compendium builds upon that utility as a standardized and comprehensive source of broadly described Major Headings and the EE costs associated with 1114 Specific Activity codes. Collectively, the revisions in the 2024 Adult Compendium provide standard MET values for adults to assist researchers, practitioners, and public health specialists in assigning and describing intensity to a wide range of PAs commonly performed in a variety of settings, including inactivity, leisure, transportation, sports and conditioning, and in-home and occupational settings. The new website with supporting materials is located at https://pacompendium.com.

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Authors' contributions

SDH conceived the study and participated in its design and coordination, carried out literature searches and article reviews, examined activities, assigned MET values, updated the website, and drafted and edited the manuscript; EAW participated in its design and coordination, carried out literature searches and article reviews, updated the website, and helped draft and edit the manuscript; BEA conceived the study and participated in its design and coordination, carried out literature searches and article reviews, examined activities, assigned MET values, and helped draft and edit the manuscript; TVB, MH, CLK, and JMS carried out literature searches and article reviews, examined activities, and helped draft and edit the manuscript; ZC carried out literature searches and article reviews, and helped edit the manuscript; MQ coordinated data collection and analysis activities, and helped edit the manuscript; DRJ Jr, CTL, and MCWG helped draft and edit the manuscript. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of authors.

Competing interests

The authors declare that they have no competing interests.

Supplementary materials

Supplementary materials associated with this article can be found in the online version at doi:10.1016/j.jshs.2023.10.010.

Appendix

DoCTER study selection process

The DoCTER process gave each article an ensemble score ranging from 0 (deemed irrelevant) to 6 (deemed relevant). Articles were then uploaded in batches to Covidence based on the highest ensemble (i.e., most relevant) score for screening and continued until stopping criteria were met. Stopping criteria for stage one was based on the proportion of articles screened as eligible in each Major Heading (i.e., cutoff <10), presented in the Supplementary Table 2. For the second screening stage, studies moved to full-text review through the first stage and were used as training data for machine learning, also through DoCTER. Each remaining unscreened study was given a probability score ranging from 0 to 1, with a higher score indicating a higher relevance ranking. Two researchers (SDH, EAW, TVB, MH, CLK, and/or JMS) again screened each title and abstract in Covidence until relevance dropped.

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