



## **Characterizing the Aerobic and Anaerobic Energy Costs of Polynesian Dances**

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### ABSTRACT

*International Journal of Exercise Science* 11(4): 1156-1172, 2018. This study characterized both aerobic and anaerobic energy expenditure (EE) for several Polynesian dances in a group of experienced professional Polynesian dancers. Thirteen men and 17 women were tested using indirect calorimetry to assess aerobic EE (and converted to METs), and fingertip blood lactate to estimate anaerobic EE, during both resting and dancing activities. Total EE was then computed as the sum of both aerobic and anaerobic activity energy expenditure (AEE, or EE above resting). One sample t-tests compared mean MET values for each type of dance to the 3-MET and 6-MET thresholds for moderate and vigorous physical activity (MVPA), respectively. Mean MET values for all dances, except the Maori poi balls dance (Mean±SD: 3.7±1.1 METs;  $P=0.340$ ), were significantly >3.0 METs (5.9±3.1 METs;  $P=0.005$  for Maori haka; 6.5±2.4 METs for Hawaiian hula; 6.6±1.2 METs for Samoan sasa; 9.6±1.5 METs for Samoan slap; 8.3±1.8 METs for Tahitian; 6.0±2.3 METs for Tongan; 7.0±2.6 METs for Fijian;  $P<0.001$ ). Mean METs for Samoan slap and Tahitian were also significantly >6.0 METs ( $P=0.002$  and  $P<0.001$ , respectively). Aerobic and anaerobic AEE contributed an average of 83.4% and 16.6%, respectively, across all Polynesian dances, with Hawaiian hula being the most aerobic (88.7%) and Samoan slap being the least aerobic (74.2%). Thus, the Polynesian dances tested not only met the current MVPA intensity guidelines (i.e.,  $\geq 3.0$  METs), each dance also had a large anaerobic EE. These data suggest that Polynesian dancing is an appropriate mode of aerobic exercise for health promotion and disease prevention.

**KEY WORDS:** Metabolic equivalent, MET, exercise prescription, Native Hawaiians, Pacific Islanders, NHOPI

### INTRODUCTION

Native Hawaiians and other Pacific Islanders (NHOPI) suffer a disproportionately high prevalence of cardio-metabolic disorders when compared with the general population of the United States (U.S.) (22). Low levels of physical activity and sedentary lifestyle are believed to be independent risk factors contributing to the higher prevalence of cardiovascular diseases (CVD), obesity, and metabolic syndrome (16) in the NHOPI population. In 2004, for example, it

was reported that 59.0% of men and 64.2% of women of the NHOPI did not meet the U.S. federally recommended levels of physical activity (PA) (7, 30). However, there is a general consensus in the literature that regular moderate-to-vigorous intensity physical activity (MVPA) that satisfies the U.S. Federal PA Guidelines (30) is associated with a lower BMI (24), reduced cardiovascular risks (17), improved glucose tolerance (28), as well as a better cognitive function (10). Thus, by encouraging regular MVPA in this population, the NHOPI could improve both cardiovascular and metabolic fitness levels, as well as decrease their risks for many chronic diseases. As such, MVPA is being used as an equivalent method of therapy for cardiometabolic diseases that has similar benefits as pharmacological treatments (13).

Polynesian dances, such as the well-known Hawaiian hula, refer to a large collection of dances that are each specific to the Polynesian cultures (e.g., Hawaiian, Fijian, Maori, Samoan, Tahitian, Tongan, etc.) and Pacific islands on which they were developed. Some of the most popular Polynesian dances are taught in schools and are practiced by men and women of all ages and ethnicities (19). Thus, Polynesian dancing could be considered a culturally specific type of PA for the at-risk NHOPI population. Waltz, aerobic dance, and Latin partnered social dance have all been studied as intervention tools for increasing MVPA in various populations and were found to improve the functional capacity and endothelium-dependent dilation (4), blood lipid profile and blood pressure (20), as well as psychological outlook for the participants (10). Thus, dancing is considered a form of PA that can induce similar physiological effects as traditional aerobic exercise training (4). In recent years, “dance therapy” has been introduced to patients with cardiovascular and metabolic diseases and has become popular (13). The Hula Empowering Lifestyle Adaptations (HELA) study, for example, successfully used hula dancing, a culturally-relevant dance to native Hawaiians, as a means for increasing MVPA and improve health benefits in cardiac rehabilitation program participants (19). Thus, dancing may be an effective form of PA for promoting healthy outcomes in populations that are receptive to dancing activities.

Unfortunately, there is relatively little objective information available about the cardiometabolic consequences of regular dancing, which makes the application of basic exercise prescription principles (i.e., determining the “dose” of exercise) difficult without knowing the metabolic demands (or exercise intensity, as commonly expressed with metabolic equivalents (MET) or energy expenditure (EE)) for each Polynesian dance. For example, there are very few MET values for culturally-based activities listed in the Compendium of Physical Activities (1), and none of these values were based upon direct measures of oxygen uptake ( $VO_2$ ). In fact, the hula is the only Polynesian dance to have direct MET intensity measures reported in the literature (5.7 and 7.6 METs for low and high intensity dances, respectively) (29). To our knowledge, the MET intensity for other Polynesian dances has never been assessed directly (e.g., using indirect calorimetry). Thus, the lack of MET intensity evaluations for most Polynesian dances may be a

deterrent to their use as MVPA intervention tools for the NHOPI and other high-risk populations.

While the *aerobic* demands for Polynesian dancing are weakly understood, the *anaerobic* energy demands of Polynesian dancing are completely undocumented. According to the literature, the traditional strategy for determining PA MET intensities is to average the last several minutes of directly-measured oxygen consumption for a steady-state bout lasting 3-10 mins. While this strategy provides the information needed to assess aerobic exercise intensity, no information is provided about anaerobic EE or anaerobic work intensity. Blood lactate measures, however, taken during the same steady-state bout have been used to estimate the anaerobic EE for both low and high intensity activities (e.g., weight lifting, rock climbing, and running) (5, 11, 26). Given that many Polynesian dances are not purely steady-state activities, it may be useful for healthcare professionals to know both the aerobic and anaerobic contributions to whole-body EE (27). However, to our knowledge, there have been no published evaluations of both the aerobic and anaerobic EE contributions for any type of dancing.

Thus, the primary purpose of this study was to measure and compare the metabolic demands (both aerobic and anaerobic) for several popular forms of Polynesian dance as commonly practiced and performed by a convenience sample of experienced professional Polynesian dancers. When expressed as a MET, these results can be compared to the guidelines of American College of Sports Medicine (ACSM) for prescribing PA and exercise (14) to determine whether dance intensity exceeds the intensity thresholds for moderate (3.0 - 5.9 METs) or vigorous intensity ( $\geq 6$  METs) PA. We hypothesized that the Polynesian dances tested would exceed the 3-MET threshold, while some of the dances (but not all) would also exceed the 6-MET threshold. Since some Polynesian dances are choreographed by gender (with men tending to have more animated and dynamic limb and body movements), we also hypothesized that the MET intensity for the men's dances would be significantly higher than that for the women's dances. Finally, given the complete lack of information regarding the anaerobic contribution to total EE of dancing, we also sought to describe how both aerobic and anaerobic energy systems contribute to total EE of Polynesian dancing.

## METHODS

### *Participants*

Participants of this study were experienced Polynesian dancers working full-time or part-time (within the past 12 months) performing the "Hā: Breath of Life" show for the Polynesian Culture Center on the island of Oahu (Hawaii, USA). Inclusion criteria included: 1) Men and women aged 18-64 yrs; 2) Native Hawaiians and other ethnic groups in Hawaii commonly identified as NHOPI; 3) Those who could perform at least one of the Polynesian dances of interest to this study. Exclusion criteria included: 1) Pregnant women; 2) Those who self-identified as having uncontrolled chronic diseases or orthopedic conditions that could adversely affect cardiometabolic measurements or the participant's ability to dance; 3) Those who had contraindications to performing MVPA. The study protocol was approved by the Brigham

Young University (BYU) – Hawaii (Laie, Oahu) Institutional Review Board. Participants read and signed the informed consent form that fully described the risks and benefits associated with participating in this study.

### *Protocol*

Participants who satisfied both inclusion and exclusion criteria were further screened with the Physical Activity Readiness Questionnaire (PAR-Q) to help identify and exclude those with contraindications to MVPA. Demographic and anthropometric data, such as age, gender, body height and mass, self-reported ethnicity, as well as total years of Polynesian dance experience, were collected at the beginning of each test session. Prior to their visit, participants were instructed to wear appropriate clothing and footwear for dancing, to be rested and well hydrated, and to avoid caffeine intake at least 2-3 hours prior to testing. Body height was measured barefoot using a portable stadiometer (Invicta Model #IP0955; Invicta Plastics Limited, Leicester, England) to the nearest 0.1 cm, and body mass was obtained to the nearest 0.1 kg using a digital scale (Tanita model #BF-683W; Tanita Corporation Tokyo Japan). These data were subsequently used to calculate body mass index (BMI, kg/m<sup>2</sup>) as body mass (kg) divided by body height (m) squared.

Participants were tested either individually (i.e., they were the only dancer tested) or in groups of two or three with all dancers being tested simultaneously. The group limit of three dancers was set to match the metabolic testing systems available. All dance testing was performed in a large ballroom with hardwood flooring on the campus of BYU-Hawaii. Participants, wearing all of the measurement equipment, began the testing with 5 minutes of quiet sitting for the determination of sitting resting metabolic rate (RMR or VO<sub>2REST</sub>) and resting blood lactate concentration ([LA<sub>REST</sub>]). Next, participants were given another 5 minutes to warm-up using self-directed activities (i.e., walking, flexibility exercises, dancing, etc.). Next, as the first piece of dance music began, the participants started the first dance routine and continued for 4.5 – 5.0 minutes before another 5 minutes of quiet sitting rest. The individual music pieces lasted from 1.5 – 3.5 minutes each, so each dance testing bout required the music piece to be looped 2 – 3 times to provide continuous music for 4.5 – 5.0 minutes. Even though these choreographed Polynesian dance routines do not usually last longer than the longest music piece (i.e., 3.5 minutes), the duration of dance testing (4.5 – 5.0 minutes) was considered necessary to provide the best opportunity for steady-state cardiorespiratory and blood lactate measures. In addition, when dancing as a group of 2 – 3 simultaneously, the dancers performed the same choreography. Finally, while most of the participants danced to the “Hā: Breath of Life” show music, a few dancers brought their own music for dancing which was characteristic of the same cultural dance style and tempo as that used in the show. This testing process (i.e., dance 5 minutes and rest for 5 minutes) was then repeated for as many of the cultural dances that the participants could perform without self-reporting undue fatigue. The order for performing the dance types was randomly assigned prior to the start of each testing session.

The Polynesian dances tested by this study were those commonly practiced and performed by professional dancers in the “Hā: Breath of Life” show at the Polynesian Culture Center (Laie,

Oahu, Hawaii). The purpose of this show was to highlight specific Polynesian cultures by combining traditional stories of each culture's origin with traditional music and dancing. As such, this show focused on six Polynesian cultures and their respective dances: 1) The Hawaiian hula (both traditional and contemporary forms) from the islands of Hawaii; 2) Traditional Fijian dance from the islands of Fiji; 3) Maori dances (the haka for both men and women, as well as poi balls for women) from New Zealand; 4) Samoan sasa (men and women) and slap (men only) dances from the island of Samoa and American Samoa; 5) Traditional Tahitian dance from the islands of Tahiti; 6) Traditional Tongan dance from the islands of Tonga.

The *Hawaiian hula*, tells a story with a combination of smoothly coordinated hand, head, and lower body motions while in a standing position. The traditional hula (Hula 'Auana) is performed to a chant and traditional Hawaiian instruments (such as drums) and is characteristic of the hula style prior to Westernization of the islands. The contemporary hula (Hula Kahiko), in contrast, is performed to music with modern instruments (such as guitar). Traditional *Fijian* dance (or Meke) reflects the spirit world and is characterized by quick upper and lower body movements with some jumping. Maori dances have two popular forms: the *haka* dance (for both men and women) is a traditional ancestral war (battle) dance during which dancers perform in a heightened arousal state inferring intimidation. The Maori *poi balls* dance (for women), using poi balls (two padded balls attached by a string) as performance equipment, integrates storytelling, singing and dancing. The Samoan culture has two main forms of dance: the *sasa* (for both men and women) and *slap* (only for men), both of which depict everyday life activities. Sasa is generally performed by a large group of people, usually in a seated position, while some parts of the dance require standing up. Slap (or Fa'ataupati) is traditionally performed by men and requires strength and stability, during which dancers forcefully slap their hands on their own bodies, in sync with each other, with hands clapping and feet stamping forwards and backwards. Traditional *Tahitian* dance is performed by men and women together or separately and is characterized by a rapid hip-shaking motion to percussion accompaniment (drums) at a fast rhythm. The traditional *Tongan* dance features story-telling through lots of hand and feet gestures. The graceful movements of women dancers contrast with the great vigor of the men dancers.

Measurement of Cardiometabolic Demands and Blood Lactate: the testing was conducted under room temperature between and 20 - 21°C, relative humidity of 57 - 71%, and at an altitude within 10 m above sea level. Each participant was fitted with a heart rate monitor chest strap (Polar Electro Inc., NY, USA) and a small backpack that carried a portable indirect calorimetry metabolic measurement system (Oxycon Mobile®; VIASYS, San Diego, CA, USA). The metabolic system was calibrated prior to each test according to the manufacturer's instructions. During all testing, participants wore a face mask affixed with an adjustable fabric headpiece which contained the flow tachometer and expired gas sampling tubes for the metabolic system. Heart rate (HR) data were transmitted to the metabolic system, while the real-time respiratory gas measures for oxygen consumption and carbon dioxide production (VCO<sub>2</sub>) were recorded continuously (breath-by-breath) throughout the participant's resting and dance testing without recalibration. The breath-by-breath sampling by the metabolic system was then used to



summarize all cardiometabolic data at one-minute sample intervals for subsequent analyses. The total mass of all testing equipment carried by participants was 1.5 kg. Fingertip blood samples were drawn for lactate analysis (Lactate Plus™, Nova Biomedical UK, Chesire, UK) right after RMR measurement (while still sitting;  $LA_{RMR}$ ,  $\text{mmol} \cdot \text{L}^{-1}$ ), as well as immediately following each dance routine ( $LA_{DANCE}$ ,  $\text{mmol} \cdot \text{L}^{-1}$ ) to characterize the anaerobic exercise intensity.

**Aerobic EE Calculations:** The MET (dimensionless) was used to represent the aerobic exercise intensity while aerobic activity energy expenditure (aerobic AEE;  $\text{kcal} \cdot \text{min}^{-1}$ ) was calculated to represent the net aerobic energy produced from the oxidative system above RMR. To determine these variables (MET and aerobic AEE), the 1-minute sample averaged data from the portable metabolic system were averaged over the last 2 minutes for each dance bout, including absolute  $VO_2$  ( $\text{mL} \cdot \text{min}^{-1}$ ),  $VCO_2$  ( $\text{mL} \cdot \text{min}^{-1}$ ), the respiratory exchange ratio (RER), and HR (BPM). First, relative  $VO_2$  ( $\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ ) was calculated as absolute  $VO_2$  ( $\text{mL} \cdot \text{min}^{-1}$ ) / mass (kg), where mass was either the participant's body mass (for RMR measurement) or the sum of body mass and the 1.5 kg equipment mass (for dance testing). Next, relative  $VO_2$  was then transformed into METs as:

$$(1) \text{ METs} = (\text{Relative } VO_2) / (3.5 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1})$$

where  $3.5 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$  is a constant that represents the adult population average for RMR. Next, EE for both dancing and RMR ( $EE_{DANCE}$  and  $EE_{RMR}$ , respectively) were calculated using Weir's equation (31):

$$(2) \text{ EE (kcal} \cdot \text{min}^{-1}) = 3.9 \times VO_2 (\text{L} \cdot \text{min}^{-1}) + 1.1 \times VCO_2 (\text{L} \cdot \text{min}^{-1})$$

where values for  $VO_2$  and  $CO_2$  were the 2-min averaged data described above for each corresponding activity. Finally, values for aerobic AEE ( $\text{kcal} \cdot \text{min}^{-1}$ ) were computed as the difference for dancing was then calculated as the difference between  $EE_{DANCE}$  and  $EE_{RMR}$ :

$$(3) \text{ Aerobic AEE} = EE_{DANCE} - EE_{RMR}$$

**Anaerobic EE Calculations.** Anaerobic AEE, or the net anaerobic energy produced from the glycolytic system while dancing, was estimated from the difference ( $[\Delta LA]$ ;  $\text{mmol} \cdot \text{L}^{-1}$ ) in circulating blood lactate concentration ( $[LA_{DANCE}]$ ) above resting values ( $[LA_{RMR}]$ ):

$$(4) [\Delta LA] = [LA_{DANCE}] - [LA_{RMR}]$$

where  $1.0 \text{ mmol} \cdot \text{L}^{-1}$  of blood lactate was assumed to be equivalent to a relative  $VO_2$  of  $3.0 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$  (8). If the computed  $[\Delta LA] \leq 0$ , then the anaerobic AEE was assumed to be zero or negligible. Otherwise, when  $[\Delta LA] > 0$ , the following formula was used to compute the anaerobic AEE ( $\text{kcal} \cdot \text{min}^{-1}$ ):

$$(5) \text{ Anaerobic AEE} = [\Delta\text{LA}] \times (3.0 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}) \times (5.0 \text{ kcals} \cdot \text{L O}_2^{-1}) \times (M_B / 1000 \text{ mL} \cdot \text{L}^{-1})$$

where  $[\Delta\text{LA}]$  and  $3.0 \text{ mL O}_2 \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$  were as described above;  $5.0 \text{ kcals} \cdot \text{L O}_2^{-1}$  was the assumed caloric equivalent (6); and the quantity  $M_B / 1000$  was used to convert the constant  $3.0 \text{ mL O}_2 \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$  into units of  $\text{L O}_2 \cdot \text{min}^{-1}$  with  $M_B$  as body mass (kg).

Total AEE ( $\text{kcal} \cdot \text{min}^{-1}$ ) was then calculated as the sum of both aerobic AEE (from measured  $\text{VO}_2$ ) and anaerobic AEE (from  $[\Delta\text{LA}]$ ) contributions:

$$(6) \text{ Total AEE} = \text{Aerobic AEE} + \text{Anaerobic AEE}$$

The contributions for both aerobic and anaerobic energy for each type of dance was expressed in both absolute ( $\text{kcal} \cdot \text{min}^{-1}$ ) and relative units (% of total AEE).

### Statistical Analysis

Intraclass correlations (ICC) for reliability were computed between the last two minutes of the raw cardiometabolic measures:  $\text{VO}_2$ ,  $\text{CO}_2$ , RER, and HR (3). Descriptive statistics were presented as mean  $\pm$  SD unless otherwise specified. A one-way ANOVA with Tukey's HSD post-hoc analysis was used to evaluate the differences in MET values across dances, while one sample t-tests were used to compare the mean MET values for each type of dance to the 3-MET and 6-MET MVPA thresholds. Gender differences in aerobic and anaerobic EE, as well as their respective contributions to total EE, were examined using independent t-tests. All statistical tests were evaluated for significance at the 0.05 alpha level, while a Bonferroni correction was used to correct the 0.05 alpha for groups of similar tests. As such, the t-tests for gender comparisons had an adjusted alpha of 0.008 ( $0.05 / 6$  tests), while the alpha level was adjusted to 0.006 ( $0.05 / 8$  tests) for the 3-MET and 6-MET threshold comparisons. All statistical analyses were conducted using SPSS 13.0 for windows (SPSS Inc., Chicago, USA).

## RESULTS

Demographic and anthropometric statistics for the 13 men and 17 women participants are listed in Table 1. According to BMI classification standards for adults (2), the men were represented within all BMI categories from underweight to obese while the women were classified within normal weight, overweight, and obese categories (see Table 1). In addition, the mean BMI values for men was significantly higher than those for women ( $P = 0.018$ ). There were no gender differences in resting HR ( $\text{HR}_{\text{REST}}$ ) or  $\text{VO}_{2\text{REST}}$ , but women had significantly lower  $[\text{LA}_{\text{REST}}]$  values ( $1.0$  vs.  $1.5 \text{ mmol} \cdot \text{L}^{-1}$ ;  $P = 0.011$ ), as well as self-reporting more Polynesian dance experience than the men ( $8.9$  vs.  $3.5$  yrs;  $P = 0.043$ ). The self-reported ethnicity for the participants was very diverse with 16 participants reporting a combination of 1 – 3 specific Polynesian ethnicities (i.e., Hawaiian, Fijian, Maori, Samoan, Tahitian, and Tongan), five others reporting either Asian ( $n = 2$ ) or Polynesian ( $n = 3$ ), and the remainder reporting a combination of  $\geq 1$  Polynesian with  $\geq 1$  non-Polynesian ethnicity (White/Caucasian, German, Japanese, or

Swedish). Finally, while one participant performed just one dance for this study, all other participants performed 4-6 individual dances.

**Table 1.** Descriptive statistics for the Polynesian dance study participants.

	All subjects (n = 30)	Men (n = 13)	Women (n = 17)
Age (yrs)	22.8 ± 3.1	24.1 ± 2.9	21.8 ± 2.9
Body height (cm)	168.5 ± 9.7	175.1 ± 9.6	163.5 ± 6.4
Body mass (kg)	79.1 ± 20.6	93.0 ± 23.4	68.4 ± 9.1
BMI (kg m <sup>-2</sup> )	27.6 ± 5.5	30.2 ± 6.7	25.6 ± 3.3
Underweight	1 <sup>a</sup>	1	0
Normal	9	3	6
Overweight	13	3	10
Obese	7	6	1
HR <sub>REST</sub> (beat min <sup>-1</sup> )	77.6 ± 12.4	75.2 ± 16.6	79.0 ± 9.5
VO <sub>2REST</sub> (mL · kg <sup>-1</sup> min <sup>-1</sup> )	3.9 ± 1.0	3.9 ± 1.0	4.0 ± 1.1
LA <sub>RMR</sub> (mmol min <sup>-1</sup> )	1.2 ± 0.5	1.5 ± 0.5	1.0 ± 0.4
Dance experience (yrs)	6.6 ± 7.3	3.5 ± 5.4	8.9 ± 7.9

All values expressed as mean ± SD unless otherwise specified. BMI: body mass index. The participant is considered underweight when BMI < 20.0; normal weight when 20 ≤ BMI < 25; overweight when 25 ≤ BMI < 30; and obese when BMI ≥ 30. HR<sub>REST</sub>: resting heart rate; VO<sub>2REST</sub>: resting oxygen uptake; LA<sub>REST</sub>: resting blood lactate concentration  
<sup>a</sup> Number of participants

Prior to summarizing the cardiometabolic data, the last two minutes of data were evaluated for intraclass reliability. First, repeated measures ANOVA found no significant differences between the last two minutes of cardiometabolic data ( $P = 0.17 - 0.95$ ). Additionally, the ICC calculations were consistently high in magnitude with all values > 0.90. Given the lack of significant differences and high ICC values, the last two minutes of cardiometabolic measurements were averaged for all subsequent analyses. Table 2 summarizes the cardiorespiratory and blood lactate responses for each of the Polynesian dances evaluated.

A preliminary analysis found that mean MET values for the traditional hula ( $5.8 \pm 1.9$ ;  $n = 6$ ) and contemporary hula ( $6.7 \pm 2.6$ ;  $n = 19$ ) were statistically similar ( $P = 0.436$ ), so these data were pooled and referred to as "hula" for all subsequent analyses. Given the varied samples sizes across dances ( $n = 3$  for poi balls to  $n = 25$  for hula), the unequal variances (SD = 1.0 to 3.1 METs), as well as the slightly skewed distributions for some samples, the samples were transformed and analyzed with the planned One-way ANOVA. The ANOVA results for the transformed data, however, did not differ from using untransformed data. Thus, the results of the ANOVA with untransformed data are reported. The ANOVA comparing mean MET values across the dances was significant ( $P = 0.001$ ), with only Maori poi balls (lowest mean MET at 3.7) and



Samoan slap (highest mean MET at 9.6) being statistically different from each other. As shown in Table 2, percent HR<sub>MAX</sub> ranged between 64.2 % (Tongan) and 79.5 % (Tahitian); RER ranged from 0.81 (Maori poi balls) to 0.95 (Tahitian); and blood lactate from 1.8 mmol · L<sup>-1</sup> (Maori haka) to 5.2 mmol · L<sup>-1</sup> (Samoan slap). Interestingly, Tahitian had both the highest percent HR<sub>MAX</sub> (79.5 %), and the highest RER value (0.95), and a moderately high [LA] (3.8 mmol · L<sup>-1</sup>), while Samoan slap had the highest [LA] (5.2 mmol · L<sup>-1</sup>) but neither the highest percent HR<sub>MAX</sub> (76.7%) nor the highest RER (0.93). Except for the Maori Poi Balls dance (3.7 METs; *P*=0.340), mean METs for all other dances were significantly greater than 3.0 METs (*P* = 0.005 for Maori haka; *P* < 0.001 for Hawaiian hula, Samoan sasa and slap, Tahitian, Tongan, and Fijian). Given, however, that the sample size for the Poi Balls dance was so low (*n*=3) and that the mean was already greater than 3.0, a greater sample size in the future could easily find that this dance also exceeds the 3.0 MET threshold. The mean MET values for Samoan slap and Tahitian were also significantly greater than the 6-MET threshold (*P* = 0.002 and *P* < 0.001, respectively).

**Table 2.** Cardiorespiratory responses and blood lactate concentration to each cultural dance routine of Polynesian dance.

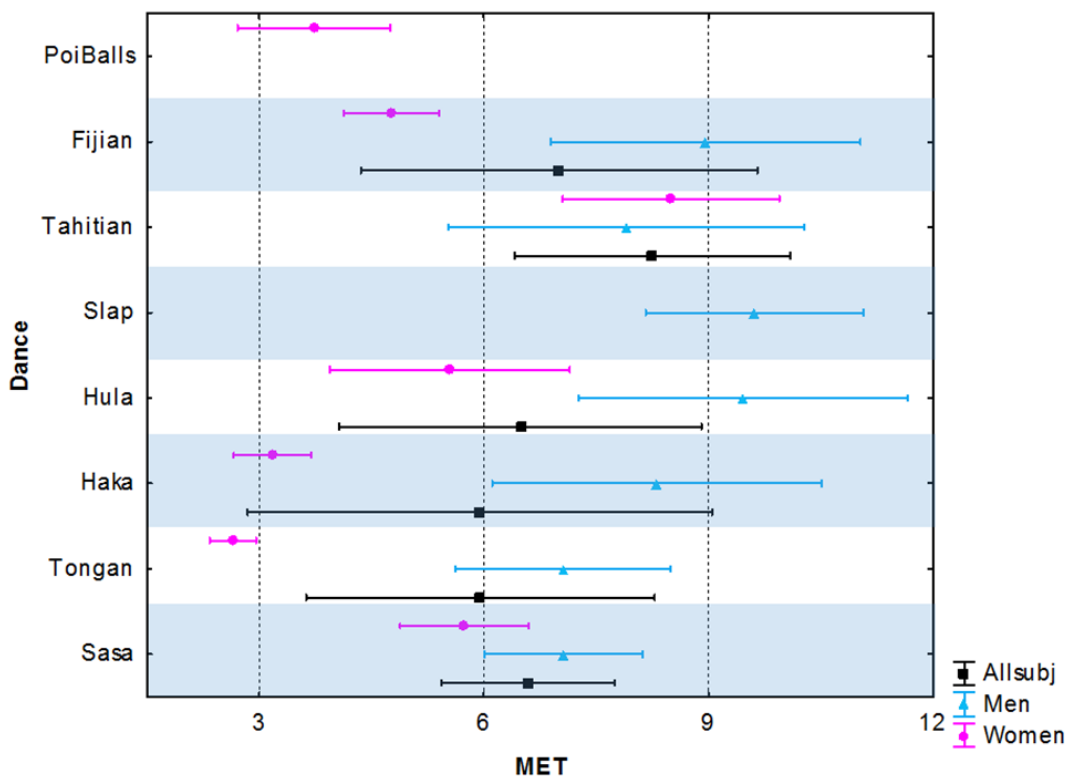
Dance (n <sup>a</sup> )	Oxygen Uptake (mL · kg <sup>-1</sup> · min <sup>-1</sup> )	MET	HR (BPM)	Percent HR <sub>MAX</sub> (%)	RER	Blood Lactate (mmol · L <sup>-1</sup> )
Hawaiian hula (n = 25)	22.7 ± 8.4	6.5 ± 2.4 *†	138.1 ± 20.3	69.7 ± 10.3	0.82 ± 0.07	2.2 ± 1.9
Fijian (n = 15)	24.5 ± 9.3	7.0 ± 2.6 *†	140.7 ± 12.9	71.3 ± 7.4	0.84 ± 0.06	2.4 ± 1.2
Maori haka (n = 13)	20.8 ± 10.9	5.9 ± 3.1 *†	127.1 ± 15.1	64.6 ± 8.2	0.82 ± 0.09	1.8 ± 1.0
Maori poi balls (n = 3)	13.0 ± 3.7	3.7 ± 1.0	130.4 ± 29.9	65.7 ± 15.2	0.81 ± 0.05	2.7 ± 2.9
Samoan sasa (n = 14)	23.1 ± 4.1	6.6 ± 1.2 *†	145.6 ± 14.2	73.1 ± 6.7	0.87 ± 0.07	3.0 ± 1.6
Samoan slap (n = 6)	33.6 ± 5.1	9.6 ± 1.5 ‡	150.5 ± 16.5	76.7 ± 8.1	0.93 ± 0.05	5.2 ± 2.0
Tahitian (n = 17)	28.9 ± 6.4	8.3 ± 1.8 ‡	156.9 ± 23.0	79.5 ± 11.3	0.95 ± 0.07	3.8 ± 2.5
Tongan (n = 16)	20.9 ± 8.1	6.0 ± 2.3 *†	127.4 ± 23.8	64.2 ± 12.2	0.88 ± 0.06	2.1 ± 1.3

All values expressed as mean ± SD unless otherwise specified. MET: metabolic equivalent; HR: heart rate; Percent HR<sub>MAX</sub>: Percent of age-predicted maximal HR, calculated as Percent HR<sub>MAX</sub> = (HR / (age-predicted maximal HR)) × 100; RER: respiratory exchange ratio (dimensionless). <sup>a</sup> Number of participants; \* Mean value for men was significantly higher than that for women; † significantly > 3 METS; ‡ significantly > 6 METS

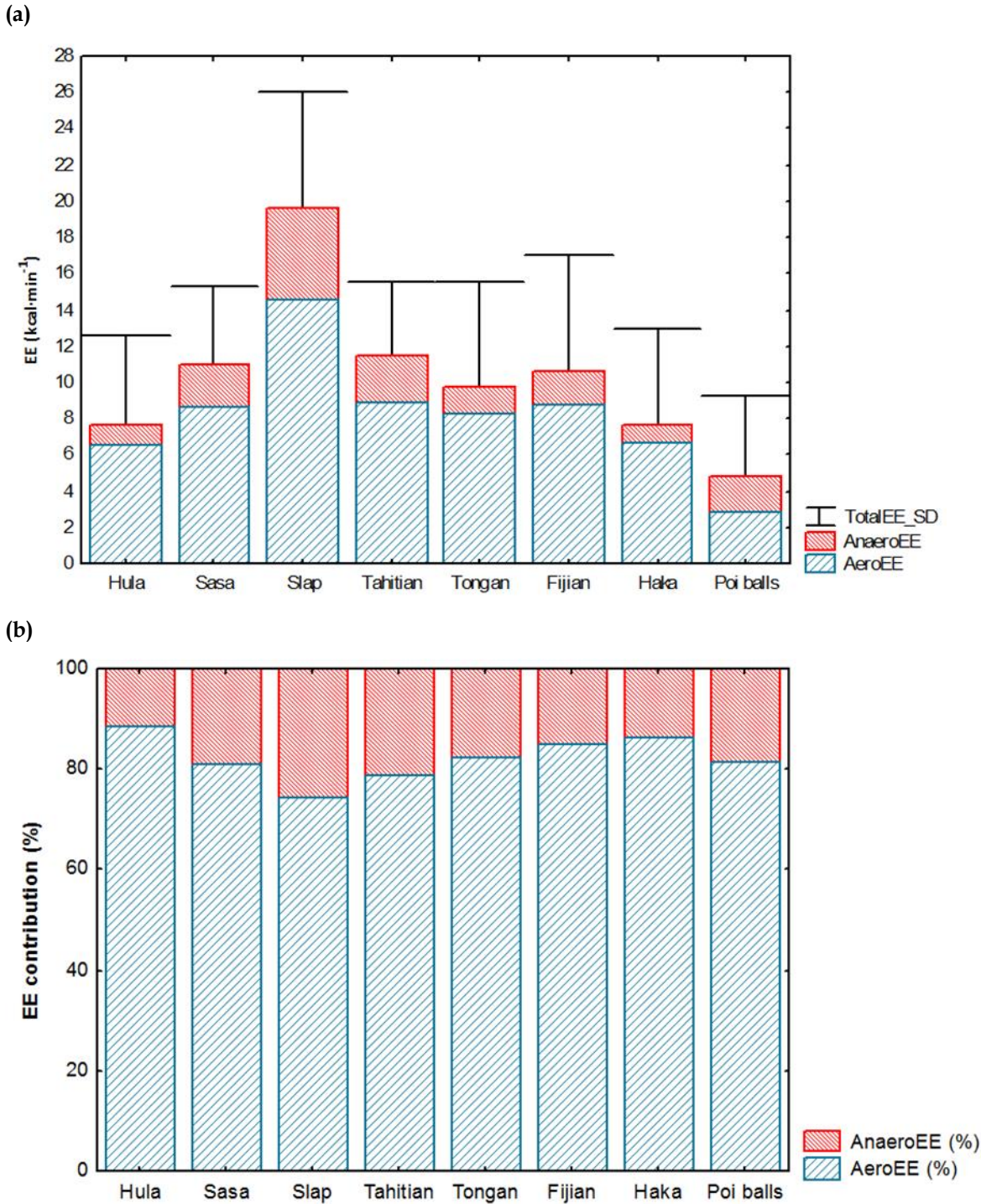
Given that five of the eight Polynesian dances (i.e., all but Tahitian, Samoan slap, and Maori poi balls) included gender-specific dance choreography with identical music, it was of interest to compare MET values by gender. However, splitting the MET data in Table 2 by gender created some extreme differences in sample size and unequal variances. Thus, in addition to the planned

t-tests, the Satterthwaite Approximation (25) was used which is a method for handling two-sample comparisons with different sample sizes and/or unequal variances. The statistical results for this technique, however, were identical to the originally-planned t-tests. Thus, just the results of the t-tests are reported. When comparing the MET values between men and women using independent t-tests, the men's MET values for Hawaiian hula, Samoan sasa, Tongan, Fijian, and Maori haka were all significantly greater ( $P < 0.001$ ; see Figure 1) than the corresponding values for women, while the Tahitian MET values were similar ( $P = 0.526$ ) between genders (see Figure 1).

Calculated results for both aerobic and anaerobic AEE for both men and women are shown in Figure 2(a), while the respective contributions of the aerobic and anaerobic AEE to the total AEE are shown in Figure 2(b). According to Figure 2, aerobic AEE was the predominant energy source for all Polynesian dances tested. The average contribution of aerobic AEE to total AEE was  $83.4 \pm 14.4\%$  with a range of 74.2% (Samoan slap) to 88.7% (Hawaiian hula). In contrast, the mean contribution of anaerobic AEE was 16.6%, with a range of 11.3% (Hawaiian hula) to 25.8% (Samoan slap). The same calculations for aerobic and anaerobic AEE, as well as the contribution of these AEE sources relative to total AEE, are summarized by gender in Table 3. The aerobic AEE for men was significantly higher than that for women dancing the Hawaiian hula, Samoan sasa, Fijian, Maori haka, and Tongan ( $P = 0.006$  for Hawaiian hula;  $P < 0.001$  for the other four types of dance). For anaerobic AEE, in contrast, there were no significant difference between men and women for the six dances performed by both genders ( $P = 0.037 - 0.500$ ).



**Figure 1.** Metabolic equivalent (MET) for eight Polynesian dances with reference to the 3.0 and 6.0 MET intensity thresholds commonly used to define moderate and vigorous exercise intensity, respectively. All values expressed as Mean  $\pm$  SD.



**Figure 2.** Aerobic and anaerobic contributions to the total energy expenditure (EE) for Polynesian dances. Mean *absolute* values for aerobic and anaerobic EE, as well as standard deviations for total EE, are provided (a) with the total EE expressed as the sum of both aerobic and anaerobic EE. The *relative* contributions of the aerobic and anaerobic energy systems to total EE for each dance tested are also shown (b).

**Table 3.** Absolute and relative rates of aerobic and anaerobic activity energy expenditure (AEE), as well as their respective contributions to total EE by gender.

	Gender (sample)	Aerobic AEE and its contribution to total AEE			Anaerobic AEE and its contribution to total AEE		
		Aerobic AEE (kcal min <sup>-1</sup> )	<i>p</i> -value*	Contribution (%)	Anaerobic AEE (kcal min <sup>-1</sup> )	<i>p</i> -value*	Contribution (%)
Hawaiian hula	M (6)	11.1 ± 4.0	< 0.001	92.2 ± 7.7	1.0 ± 1.0	0.822	7.8 ± 7.7
	W (19)	5.0 ± 2.1		87.6 ± 15.1	1.3 ± 2.3		12.4 ± 15.1
Fijian	M (8)	12.8 ± 4.3	< 0.001	84.6 ± 5.5	2.4 ± 1.1	0.110	15.4 ± 5.5
	W (7)	4.3 ± 1.0		85.0 ± 14.5	1.1 ± 1.8		15.0 ± 14.5
Maori haka	M (7)	10.2 ± 3.4	< 0.001	88.0 ± 10.1	1.4 ± 1.1	0.087	12.0 ± 10.1
	W (6)	2.5 ± 0.5		83.8 ± 9.5	0.5 ± 0.3		16.2 ± 9.5
Maori poi balls	W (3)	2.9 ± 1.4	N.A.	81.5 ± 32.1	1.9 ± 3.2	N.A.	18.5 ± 32.1
Samoan slap	M (6)	14.5 ± 4.8	N.A.	74.2 ± 10.9	5.1 ± 3.0	N.A.	25.8 ± 10.9
Tahitian	M (7)	9.8 ± 3.6	0.312	84.1 ± 14.1	1.5 ± 1.1	0.138	15.9 ± 14.1
	W (10)	8.3 ± 2.1		75.3 ± 14.1	3.4 ± 3.0		24.7 ± 14.1
Tongan	M (12)	10.5 ± 3.7	< 0.001	90.0 ± 10.0	1.4 ± 2.4	0.989	10.0 ± 10.0
	W (4)	1.9 ± 0.4		58.5 ± 16.3	1.4 ± 0.6		41.5 ± 16.3

All values expressed as mean ± SD unless otherwise specified. M: men; W: women. \* Mean value for Aerobic AEE or Anaerobic AEE was significantly higher for men than that for women

## DISCUSSION

The present study provides insight into both aerobic and anaerobic metabolic demands for several popular Polynesian cultural dances. Our results indicate that all Polynesian dances tested, except for the Maori poi balls dance, have MET intensities that exceed the 3-MET MVPA threshold, and thus may be considered an appropriate PA for the at-risk NHOPI population to meet the current recommendations for PA and exercise prescription (14). It was also clear that the men's dances tended to have much higher MET values than the women's dances (i.e., Hawaiian hula, Fijian, Maori haka, Samoan sasa, and Tongan) so both gender and the type of Polynesian dance should to be considered together when designing a dance-specific PA intervention program.

The mean MET values for the Polynesian dances evaluated by this study ranged broadly from a low of 3.7 METs for Maori poi balls to a high of 9.6 METs for the Samoan slap (Table 2). Interestingly, the Maori poi balls and Samoan slap were also the only two dances specific to one gender (women and men, respectively). The mean MET values for the other six dances were more similar (5.9 – 8.3 METs; Table 2) but included both men and women dancers. When compared to the 3-MET and 6-MET thresholds for MVPA, all but Maori poi balls exceeded 3 METs, while only Samoan slap and traditional Tahitian exceeded 6 METs. Thus, the hypothesis that all Polynesian dances tested would exceed the 3-MET threshold was nearly satisfied, while the hypothesis that only some (not all) of the dances would exceed the 6-MET threshold held true.



Comparable MET data for Polynesian dancing is relatively scarce in the published research literature. The Hawaiian hula, for example, appears to be the only Polynesian dance previously reported upon with direct measures of  $\text{VO}_2$ . Usagawa et al. (29) evaluated the Hawaiian hula (described by the authors as a combination of traditional and contemporary forms of hula) in competitive Polynesian dancers and reported mean MET values of 5.7 and 7.6 METs for slow tempo (low-intensity) and fast tempo (high-intensity) hula, respectively. The present study measured traditional and contemporary hula separately and found these two sub-styles of hula to be statistically similar (5.8 and 6.7 METs, respectively;  $P = 0.436$ ). Regardless, both of these evaluations for hula, whether the style was traditional, contemporary, or some combination, consistently report the intensity to exceed the 3-MET threshold but not the 6-MET threshold. Focusing on ballroom dancing, Lankford et al. (18) reported that the exercise intensity of four ballroom dances (5.3, 5.3, 6.4, and 7.1 METs for waltz, foxtrot, cha cha, and swing, respectively) with recreational dancers also exceeded the 3-MET threshold. Recent work from our own lab (32) focused on evaluating the metabolic demands for Tinikling, a traditional Philippine bamboo dance. Using mostly middle-aged adults with a recreational familiarity of the dance style, Tinikling had a mean MET intensity of 6.9 METs which exceeded the 6-MET threshold ( $P = 0.0015$ ). The commonality amongst these dance studies is that MET values were based upon the indirect calorimetry technique for assessing aerobic metabolic demands. However, despite the different types of dances reported upon (Polynesian, ballroom, Tinikling), the different populations assessed (competitive and professional dancers, as well as college-aged and middle-aged dancers), the results consistently suggest that many forms of dance have a metabolic demand that easily exceeds the 3-MET threshold, while some also exceed the 6-MET threshold.

**Gender Comparisons:** the result of the present study supported our second hypothesis that the MET intensities for some of the men's dances would be significantly higher than those for the women's dances (see Figure 1). Five of the six Polynesian dances performed by both men and women (i.e., Hawaiian hula, Fijian, Samoan sasa, Maori haka, and Tongan) had gender-specific choreography while dancing to identical music. For example, the Maori haka (a traditional battle dance) has men and women performing in a heightened arousal state that encourages yelling with exaggerated facial expressions. However, the men's haka emphasizes high-intensity upper and lower body motions, while the women's haka involves relatively quiet standing and less exaggerated upper body motions. These choreography differences explain why women's haka had a metabolic demand of only 3.2 METs while the men's haka averaged 8.3 METs. Tahitian was the only dance that had no significant gender difference in MET values, and could also be classified as vigorous-intensity PA for both genders.

The lower metabolic demands exhibited by the women dancers might also due to the women dancers reporting more Polynesian dance experience than the men (8.9 vs. 3.5 yrs;  $P = 0.043$ ). This observation is consistent with the women hula dancers in Usagawa's study (29) who started training at the age of 5 while men dancers started in late adolescence or early adulthood. As such, it is presumed that more years of dance experience would lead to higher dancing skill levels and possibly more energetically efficient dance movements. However, this explanation seems unlikely given the contrast in choreography between men and women dancers described



above. While a movement analysis was not performed on these dancers, the visual appearance of the men's dance choreography often appeared more highly energetic (i.e., jumping, stomping, dynamic large range of motion gestures) while the women's dances appeared relatively subdued (i.e., smooth and graceful body motions without jumping or stomping). Finally, the men in the present study also had a significantly higher BMI ( $30.2 \text{ kg m}^{-2}$ ) than the women dancers ( $25.6 \text{ kg m}^{-2}$ ) which could have increased the aerobic energy cost for men simply because of having more body mass when dancing. While having a higher BMI most certainly contributed to a higher absolute energetic costs for dancing, it is still more likely that differences in dance choreography between genders was the primary cause for gender differences amongst five of the Polynesian dances tested in this study.

**Aerobic AEE:** as for aerobic AEE, we observed the mean values for the Hawaiian hula, Fijian, Maori haka, Samoan sasa, Samoan slap, as well as the traditional Tahitian and Tongan dances to range between  $6.5$  and  $14.5 \text{ kcal min}^{-1}$  (see Figure 2a). Previous dance studies, such as Lankford et al.'s recreational ballroom dance study (18), reported that waltz, foxtrot, cha cha, and swing cost an average of  $5.9 \text{ kcal min}^{-1}$ . For Latin American dancing, Massidda et al. (21) reported metabolic rates of  $9.9$ ,  $8.3$ ,  $6.6$ ,  $8.5$ , and  $8.3 \text{ kcal min}^{-1}$  for cha cha, samba, rumba, paso doble, and jive, respectively. Emerenziani et al. (12) measured the AEE in three different forms of salsa dance: typical salsa lesson ( $5.6$  and  $4.5 \text{ kcal min}^{-1}$ ), rueda de casino lesson ( $6.8$  and  $5.3 \text{ kcal min}^{-1}$ ), and salsa dancing at night club ( $7.1$  and  $4.2 \text{ kcal min}^{-1}$ ), for men and women, respectively. These data are comparable to our findings for Hawaiian hula ( $6.5 \text{ kcal min}^{-1}$ ), Samoan sasa ( $8.6 \text{ kcal min}^{-1}$ ), Tahitian ( $8.9 \text{ kcal min}^{-1}$ ), Tongan ( $8.3 \text{ kcal min}^{-1}$ ), Fijian ( $8.8 \text{ kcal min}^{-1}$ ), and Maori haka ( $6.7 \text{ kcal min}^{-1}$ ), though the present study is the only one to have also assessed the anaerobic energy cost.

**Anaerobic AEE:** it is well known that the aerobic and anaerobic energy contributions to total EE during PA will change in response to exercise intensity and duration (23), as well as with exercise modalities (27). Unlike many classic forms of aerobic exercise (e.g., walking, jogging, bicycling), many Polynesian dances are not purely steady-state activities due to changes in choreography that correspond with changes in music tempo and duration. Thus, a better understanding of the aerobic and anaerobic energy system contributions to total EE during dance may be important for correct administration and structuring of exercise prescription. To our knowledge, this is the first study to evaluate both absolute ( $\text{kcal min}^{-1}$ ) and relative (% of total AEE) aerobic and anaerobic AEE for any type of dancing. In short, the current study found that aerobic energy was predominantly used for all Polynesian dances tested. On average, aerobic and anaerobic AEE contribute  $83.4\%$  and  $16.6\%$ , respectively, to total AEE for Polynesian dances (see Figure 2b). Across dances, the Hawaiian hula had the highest aerobic energy contribution ( $88.7\%$  aerobic and  $11.3\%$  anaerobic for a total AEE of  $7.7 \text{ kcal min}^{-1}$ ), while Samoan slap had the lowest aerobic energy contribution ( $74.2\%$  aerobic and  $25.8\%$  anaerobic for a total AEE of  $19.6 \text{ kcal min}^{-1}$ ). These aerobic energy contributions are comparable to other endurance exercises, such as  $1500 \text{ m}$  track running ( $77\%$  and  $86\%$  for men and women, respectively),  $3000 \text{ m}$  track running ( $86\%$  and  $94\%$  for men and women, respectively) (11), and  $2000 \text{ m}$  rowing ( $87\%$ ) (9). By referring to findings of our study (i.e., the aerobic and anaerobic AEE contributions to

total AEE), health practitioners and researchers could design intervention programs using one or more forms of Polynesian dance that have absolute or relative aerobic AEE equivalent to traditional exercise modalities.

**Limitations and Future Research:** one limitation of this study is that our participants were all experienced professional Polynesian dancers. Novice or beginner dancers may have somewhat different cardiometabolic responses to these forms of dance. While the dependence of cardiometabolic responses on dance experience has been suggested (5), the topic does not seem to have been studied or reported upon in the literature. Second, all the dance testing was performed for a duration of 4.5 – 5 mins to ensure that the participants reached steady-state for respiratory gas analysis. Given that exercise duration may influence the metabolic fate of blood lactate concentration (15), the anaerobic AEE estimates from our study will correspond most directly with steady-state dancing (3+ mins in duration). Further, our estimates of both aerobic and anaerobic AEE are limited to steady-state measurement conditions – i.e., Our measures will be less accurate for dances of very short duration, as well as dances that are non-steady-state in nature. Other study limitations include the small sample sizes for some of our dance data (e.g.,  $n = 3$  for the Maori poi balls dance), and that an objective measure of aerobic fitness, such as maximal oxygen uptake ( $VO_{2MAX}$ ), was not measured for our dance participants.

Future research should consider using dancers with a more diverse range of dance experience and skill to provide a more complete understanding of the energy cost for Polynesian dancing. Also, various durations of dancing exercise should also be addressed in future studies to provide better evidence of the energy system contributions to Polynesian dancing. Finally, the current study's analysis of both aerobic and anaerobic contributions to total EE should be expanded to other types of dance to determine the generalizability of our observations.

This is the first study to directly measure with indirect calorimetry the aerobic energy cost of multiple Polynesian dances, as well as the contribution of anaerobic energy to the total energy cost for these dances. For aerobic energy costs, we found that the average MET intensity for most of the Polynesian dances evaluated (Hawaiian hula, Samoan sasa and slap, Fijian, Maori haka, and Tongan, but not Maori poi balls) exceeded the 3-MET threshold. However, when evaluated by gender, the men's MET values were significantly higher than the women's values for all but traditional Tahitian dance. Thus, while these results support the use of Polynesian dancing as a means to promote increased MVPA for health promotion and diseases prevention for the NHOPI population, the cardiometabolic dose to be expected will vary between Polynesian dances, as well as between genders. In addition, we also found that the dancers' heavy reliance upon aerobic energy (83.4%) versus anaerobic energy (16.6%) is actually very similar to other more traditional aerobic activities such as distance running and rowing. Collectively, the results from the present study can serve as a starting reference for the prescribed use of Polynesian dancing by health practitioners, coaches, exercise physiologist and researchers.

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