Oxygen Consumption during Viniyoga Practice in Adults

Abstract

Context: The purpose of this study was to measure the oxygen consumption (VO₂) during Viniyoga yoga movements (asanas) and to compare VO₂ walking among adults. Methods: Yoga practitioners (n = 10) were recruited to measure VO₂ while at rest (30 min), practicing yoga (16 movements with different variations), and treadmill walking at 2 mph (10 min) and 3 mph (10 min). VO₂ was measured using a whole-room indirect calorimetry. Each yoga movement was categorized by body orientation as standing, lying, and sitting. The differences in VO₂ between yoga and walking were examined using Pearson’s correlations. Differences in VO₂ between poses (standing, sitting, and lying) were examined using linear regression models. VO₂. Results: Mean yoga-VO₂ for the entire yoga session was 3.7 (standard deviation [SD] 0.43, range: 4.4–8.9) ml/kg/min. Yoga-VO₂ varied by body orientation: standing = 7.5 (SD = 1.5) ml/kg/min, lying = 5.3 (SD = 1.0) ml/kg/min, and sitting = 5.4 (SD = 1.1) ml/kg/min. After adjusting for body mass, frequency of yoga practice, and resting energy expenditure, female gender was negatively associated with mean yoga VO₂ for standing (B = −112.19, P < 0.05), lying (B = −141.87, P < 0.05), and sitting (B = −129.96, P < 0.05). Mean VO₂ for walking 2 mph was comparable with sitting (r = 0.836, P < 0.05) and lying (r = 0.735, P < 0.05) whereas walking at 3 mph was comparable with standing (r = 0.718, P < 0.05) and sitting (r = 0.760, P < 0.05). Conclusion: We conclude that VO₂ during yoga practice is comparable to VO₂ during slow treadmill walking and may vary based on gender and body orientation.

Keywords: Energy expenditure, mind-body practice, oxygen consumption, yoga

Introduction

The National Health Interview Survey identified yoga as the most common mind-body practice used for health with 21 million practitioners in the United States. More than half of the practitioners reported doing yoga for physical fitness. While very popular, yoga is an atypical form of exercise. Conventional aerobic exercise encourages increasing the physical intensity of activity, which leads to increased heart and respiratory rate and energy expenditure. In contrast, yoga traditionally emphasizes slow breathing during movement. Movements are performed ideally with ease and comfort, rather than strenuous effort. Finally, yoga uses physical movements coupled with slow breathing as a method to focus the mind.

These three characteristics of yoga (slow breathing, movement with ease, and mental focus) distinguish yoga from conventional aerobic exercise.

Variations in yoga styles, techniques, and emphasis on movement make it difficult to categorize yoga’s physical intensity. Yoga movements are called asana in Sanskrit (an ancient Indian language), which is often translated as pose. This can be misleading as asana includes movements required to enter and exit a pose. Asana may be performed as follows: (1) dynamically where the pose is entered and exited repeatedly in succession; (2) statically where the final position is held for a specified period; or (3) a combination of both dynamic and static. We will refer to asana as movement in this paper. Variations in how yoga is performed, dynamically or statically, may impact intensity. A recent review reported that the physical intensity of yoga movements ranges from low (<3 METS)-to-moderate intensity (3–6 METS).[4] These data suggest that much of yoga may not achieve sufficient physical intensity for cardiovascular benefits within the context of conventional aerobic exercise.

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Viniyoga, a style of yoga originating from Krishnamacharya and his son T. K. V. Desikachar, has had substantial influence on modern yoga styles. This yoga style emphasizes linking breath to all physical movements. Furthermore, Viniyoga proposes to adapt the yoga to the functional needs and abilities of the individual. While physical movements in Viniyoga are well described, there are many potential variations and modifications of movements.[5,6] In addition, oxygen consumption (VO₂) for performing separate Viniyoga movements and a series of movements are unknown. The objective of this study was to measure the VO₂ of adults practicing common Viniyoga yoga movements with different variations. In addition, participants were asked to walk at low and moderate intensities to compare VO₂ of a comparative aerobic exercise.

**Methods**

**Study population**

The principal investigator has regular professional communication with yoga teachers in Middle Tennessee through E-mail and phone. Viniyoga practitioners in the Nashville community were approached to participate in the study by E-mail. Inclusion criteria were regular yoga practice at least four times a week, age 18 years or older, and English speaking. Exclusion criteria included self-reported medical conditions that are contraindications to regular exercise after review of medical history by the principal investigator (GB).

**Informed consent and use of human subjects**

Informed consent was obtained from all individual participants in the study, and the consenting process was approved by the Vanderbilt University Medical Center Institutional Review Board.

**Study protocol**

The yoga protocol for this study was developed by the senior author (GB) in consultation with experts in Viniyoga. Yoga movements were selected based on commonly used movements in Viniyoga. Yoga movements, orientation of body, variations selected, and number of repetitions are shown in Table 1. Since yoga movements in Sanskrit do not have English equivalents, a brief description of each movement is provided. Movements were sequenced in an order consistent with traditional Viniyoga (standing, lying, then seated).[5,6] In addition, breathing is closely linked to each movement, where practitioners breathe deeply and slowly with each movement, but are advised to not become short of breath. Since individuals have different breath capacity, the time to perform yoga movements varied.

After admission to the Clinical Research Center (CRC), weight, height, and bioelectric impedance analyzer (BIA) measurements participants enter the whole-room calorimeter for a yoga session. After a short acclimatization period (~10 min), participants were asked to lie down on a yoga mat and the rest for 30 min. During this time, resting VO₂ (rest-VO₂) was measured. After the rest, participants began performing yoga movements [Table 2] separated by a 1-min rest. The rest period consisted of no physical movement while staying in the same body orientation. Variations of a single yoga movement were performed successively to understand if these produce differences in VO₂. Two main variations included static movement (staying in the yoga pose for one breath) and dynamic movement. For squats, we also evaluated the VO₂ of a specific yoga technique, where movements were performed while holding the breath (anga langhavan). An equal number of asymmetric movements were performed on both body sides. Viniyoga emphasizes that breathing be slow and comfortable during all movements. Since individuals have varying breath capacity, yoga movements were performed for different durations to accommodate differences in breath.

**Exercise protocol**

After finishing yoga protocol, participants rested in the supine position for 10–15 min. Participants then walked on the treadmill at 2 mph for 10 min. After 10–15 min rest, participants walked on the treadmill at 3 mph for 10 min, rested, and were discharged from the CRC.

**Demographic, anthropometric, and yoga practice-related data collection**

Age, gender, practicing yoga duration, weekly practice frequency, length of practice (minutes), and types of yoga practiced were self-reported.

**Anthropometric measurements**

We calculated body mass index (BMI-kg/m²) from measured body weight and height. Body composition (fat mass, lean mass, and total body water) was assessed using BIA (Tanita Progressional Segmental Body Composition Analyzer/Scale Model BC418).[7] VO₂ was measured using a whole-room indirect calorimetry located at the CRC at Vanderbilt University Medical Center. The small room is airtight with windows, toilet, and sink, and for this study

| **Table 1: Participant characteristics (n=10)** |
|-----------------------------------------------|
| **Means±SD**                                  |
| Females                                      | 6 |
| Age                                          | 38.10±8.62 |
| BMI                                          | 23.91±3.16 |
| Total body water (kg)                        | 85.21±18.22 |
| Total fat mass (kg)                          | 33.05±15.75 |
| Total predicted lean muscle mass (kg)        | 110.79±23.96 |
| Years practicing yoga                        | 12.35±7.59 |
| Weekly practice adherence                    | 6.2±1.01 |
| Practice length (min)                        | 50.25±14.65 |
| SD=Standard deviation, BMI=Body mass index  |


| Sanskrit name (common English) | Description                  | Asana(s) reference number | Narrative description                        | Repetitions (n) | \( \text{VO}_2 \) (l/kg/min)* \((n=10)\) |
|-------------------------------|------------------------------|---------------------------|----------------------------------------------|-----------------|------------------------------------------|
| **Standing**                  |                              |                           |                                              |                 |                                          |
| Uttanasana                    | Forward fold                 | 1.0                       | Dynamic, coming back to standing             | 6               | 5.6±0.98                                  |
|                               |                              | 1.2                       | Stay 1 breath in pose                        | 6               | 6.7±1.3                                   |
|                               |                              | 1.3                       | Dynamic, do not return to standing           | 6               | 6.8±1.4                                   |
| Ardha uttananasana            | Half-forward fold            | 2.1                       | Dynamic, coming back to standing             | 6               | 7.0±1.1                                   |
|                               |                              | 2.2                       | Stay 1 breath in pose                        | 6               | 7.0±0.93                                  |
|                               |                              | 2.3                       | Dynamic, do not return to standing           | 6               | 7.2±1.1                                   |
| Uttkatasana                   | Squat                        | 3.1                       | Dynamic, coming back to standing             | 6               | 8.1±0.89                                  |
|                               |                              | 3.2                       | Stay 1 breath in pose                        | 6               | 8.8±1.1                                   |
|                               |                              | 3.3                       | Dynamic, do not return to standing           | 6               | 8.9±1.1                                   |
|                               |                              |                           | Angalangavan, after exhale as you go into position | 6               | 8.6±0.92                                  |
| Ardha utkatasana              | Half-squat                   | 4.1                       | Dynamic, coming back to standing             | 6               | 8.5±1.1                                   |
|                               |                              | 4.2                       | Stay 1 breath in pose                        | 6               | 8.9±1.4                                   |
|                               |                              | 4.3                       | Dynamic, do not return to standing           | 6               | 8.9±1.6                                   |
| Parsva uttananasana           | Side split forward bend (both sides) | 5.1               | Dynamic, coming back to standing             | 6 (3 on each side) | 8.4±1.7                                   |
|                               |                              | 5.2                       | Stay 1 breath in pose                        | 3 on each side | 8.0±1.6                                   |
|                               |                              | 5.3                       | Dynamic, do not return to standing           | 3 on each side | 7.6±1.3                                   |
| Trikonasana parsva (both sides) | Front split lateral bend       | 6.1                       | Dynamic, coming back to standing             | 3 on each side alternating | 6.7±0.91                                   |
|                               |                              | 6.2                       | Stay for 1 breath in pose                    | 3 on each side alternating | 6.1±1.2                                   |
|                               |                              | 6.3                       | Dynamic, do not return to standing           | 3 on each side alternating | 6.3±1.3                                   |
| Trikonasana parivritti (both sides) | Front split twisting forward bend | 7.1                       | Dynamic, coming back to standing             | 3 on each side alternating | 6.6±1.1                                   |
|                               |                              | 7.2                       | Stay 1 breath in pose                        | 3 on each side alternating | 7.3±1.6                                   |
|                               |                              | 7.3                       | Dynamic, do not return to standing           | 3 on each side alternating | 7.2±1.5                                   |
| Virabhadrasana                | Forward lunge with arms raised overhead | 8.1                       | Dynamic, coming back to standing             | 3 on each side | 7.0±1.1                                   |
|                               |                              | 8.2                       | Stay 1 breath in pose                        | 3 on each side | 7.0±1.0                                   |
|                               |                              | 8.3                       | Dynamic, coming back to standing             | 3 on each side | 7.2±1.4                                   |
| Udhipa mukha svasana (modified) | Forward bend against wall moving to back extension | 9.1                       | Dynamic, coming back to standing             | 6               | 6.8±1.4                                   |
|                               |                              | 9.2                       | Stay 1 breath in pose                        | 6               | 6.6±1.5                                   |
| Surya namaskar (Sun salutation) | Common sequence of yoga movements | 10.1                      | Dynamic                                      | 3 rounds (left and right) | 8.5±1.2                                   |
|                               |                              | 10.2                      | Stay 1 breath                               | 1 round (left and right) | 8.7±1.3                                   |

Contd...
was equipped with a yoga mat, chair, and treadmill. The research staff and participants can see each other through a glass window connected to an anteroom, and communicated through an intercom.

\[\dot{V}O_2\], air flow rate, temperature, barometric pressure, and humidity of the air were sampled at 60 times per second and integrated at the end of each minute to calculate \(\dot{V}O_2\) on a minute-by-minute basis.\[8\] This system has an accuracy of >90% within a minute and allows measurement of \(\dot{V}O_2\) during short exercise periods.\[9\]

\(\dot{V}O_2\) at rest (ml/kg/min) was defined as the average \(\dot{V}O_2\) during a 30-min in lying (supine) position with minimal movement and was calculated from the last 10 min of measurement during the rest.

Mean \(\dot{V}O_2\) (ml/kg/min) and energy expenditure as metabolic equivalents [METS] were assessed as the absolute \(\dot{V}O_2\) for grouped yoga movements (standing, lying, and sitting), walk at 2 mph, and walk at 3 mph.

Statistical analyses

We used descriptive statistics to report demographics, body composition, and \(\dot{V}O_2\) by activity. The increase in \(\dot{V}O_2\) was for yoga activities and walking was calculated in relation to baseline rest period. The relationship between yoga and walking at 2 and 3 mph was used to examined using Pearson’s correlations. Mean \(\dot{V}O_2\) by weight for total yoga practice, walk at 2 mph, and walk at 3 mph were compared using the Mann–Whitney U Test. Linear regression models were built with mean Yoga-\(\dot{V}O_2\) as the dependent variable for three categories of movement: standing, lying, and sitting. The independent variables in the model were gender, BMI, practice frequency, and mean \(\dot{V}O_2\)‑rest period. \(P < 0.05\) was considered statistically significant. Statistical analyzes were performed using IBM SPSS Version 24.0 (SPSS Inc., Chicago, IL, USA).

Results

Participants \((n = 10, 4\) males) and yoga practice characteristics are displayed in Table 1. Nine participants currently practiced Viniyoga. The mean \(\dot{V}O_2\)-rest period was 3.7 (standard deviation [SD] 0.43) ml/kg/min. Table 2 lists the \(\dot{V}O_2\) for each movement and variations performed. The average \(\dot{V}O_2\) for movements ranged from 4.4 to 8.9 ml/kg/min. After grouping the movements by body orientation, the mean \(\dot{V}O_2\)-yoga were as follows: standing = 7.5 (SD1.5) ml/kg/min; lying = 5.3 (SD 1.0) ml/kg/min; and sitting = 5.4 (SD 1.1) ml/kg/min. Energy expenditure for yoga movements by body orientation were standing = 2.15 (SD 0.3) METS; lying = 1.52 (SD 0.3) METS; sitting = 1.5 (SD 0.3) METS; walk at 2 mph = 1.9 (SD 0.3) METS; and walk at 3 mph = 2.2 (SD 0.3) METS. Sun salutations (surya namaskar), a common yoga sequence, was 2.4 (SD 0.3) METS.

Table 2: Contd...

| Sankrít name (common English) | Description | Asana (s) reference number | Narrative description | Repetitions (n) | \(\dot{V}O_2\) (l/kg/min)\[^{a}\] (n=10) |
|-----------------------------|-------------|---------------------------|-----------------------|----------------|----------------------------------|
| **Supine**                  |             |                           |                       |                |                                  |
| Urdhva prasrita padasana (modified) | Move from knees to chest to legs extended overhead | 11.1 Dynamic | 6 | 6.5±1.2 |
| Dvipadapitham | Declined bridge | 11.2 Stay 1 breath | 6 | 6.0±1.2 |
| Apanasana | Knees to chest | 12.1 Dynamic | 6 | 5.7±1.1 |
| Jathararavivritti | Knees to side twist | 12.2 Stay 1 breath | 6 | 5.6±1.1 |
| Mahamudra | Knee bent and abducted, fold partially forward while keeping spine extended | 13.1 Dynamic | 6 | 4.9±1.1 |
| Pasmitanasana | Forward fold | 13.2 Stay 1 breath | 6 | 4.9±1.0 |
| **Seated**                  |             |                           |                       |                |                                  |
| | | 14.1 Dynamic, back to sitting | 3 on each side alternating | 4.4±0.82 |
| | | 14.2 Stay 1 breath | 3 on each side alternating | 4.5±1.2 |
| | | 15.1 Stay 6 breaths | 3 on each side | 5.4±1.3 |
| | | 15.2 Stay 6 breaths, hold after exhale 3 to 6 | 3 on each side | 5.5±1.1 |
| | | 16.1 Dynamic and back to sitting | 6 | 5.9±1.5 |
| | | 16.2 Dynamic and stay one breath | 6 | 5.9±1.6 |
| | | 16.3 Dynamic and not back to standing | 6 | 6.1±1.6 |

\[^{a}\]mean±SD. SD=Standard deviation, \(\dot{V}O_2\)=Oxygen consumption
The mean \( \text{VO}_2 \)-walking was 6.8 (SD 0.9) ml/kg/min at 2 mph and 7.8 (SD 0.9) ml/kg/min at 3 mph. Figure 1 displays a scatterplot and \( \text{VO}_2 \) for each movement and walking. There were no significant differences in mean \( \text{VO}_2 \) for variations of each pose. In general, mean \( \text{VO}_2 \) was lower during lying and sitting than standing movements. Lying and sitting movements had similar \( \text{VO}_2 \). Mean \( \text{VO}_2 \) by weight (ml/kg/min) for total yoga practice was significantly different between women and men \((U = 0.0, P = 0.01)\). However, mean \( \text{VO}_2 \) by weight (ml/kg/min) for walk at 2 mph and 3 mph were not significantly different between genders: \((U = 3.0, P = 0.07)\) and \((U = 6.0, P = 0.26)\), respectively. We built three regression models with \( \text{VO}_2 \) as the dependent variable and gender, BMI, weekly frequency of practice, and mean \( \text{VO}_2 \)-rest period (ml/kg/min) as independent variables. All three multiple linear regression models were with gender significantly accounting for variance in mean \( \text{VO}_2 \) during grouped movements (standing \([F [4, 5] = 10.81, P < 0.01] \) \( r^2 = 0.896 \); lying \([F [4, 5] = 12.519, P < 0.01] \) \( r^2 = 0.909 \); and sitting \([F [4, 5] = 19.501, P < 0.01] \) \( r^2 = 0.940 \)). Being female was negatively associated with \( \text{VO}_2 \) during standing \((B = −112.19, P < 0.05)\), lying \((B = −141.87, P < 0.05)\), and sitting \((B = −129.96, P < 0.05)\). Mean \( \text{VO}_2 \)-rest period was also significantly associated with mean \( \text{VO}_2 \) for sitting movements \((B = 1.08, P < 0.05)\). BMI and weekly frequency of practice were not significant independent factors in regression models.

In Figure 2, we calculated the percentage increase in \( \text{VO}_2 \) from resting by activity. In Table 3, we display correlations between yoga and walking at 2 and 3 mph on the treadmill. Walking at 2 mph correlated significantly \( \text{VO}_2 \) with performing lying and sitting yoga movements whereas walking at 3 mph correlated significantly with performing standing and sitting movements [Table 3]. The \( \text{VO}_2 \) for all yoga activity combined significantly correlated with walking at 2 and 3 mph.

**Discussion**

We found that when compared to rest, Viniyoga yoga increased \( \text{VO}_2 \) by an estimated 100% for standing and 40% for lying and sitting movements. There were no significant differences in \( \text{VO}_2 \) by variations for each movement (dynamic or static). Overall, there was a 2-fold variation among yoga practitioners in \( \text{VO}_2 \). Gender significantly accounted for variation in \( \text{VO}_2 \) with women consuming <men. \( \text{VO}_2 \) while practicing yoga correlated significantly with walking at 2 and 3 mph.

This study used indirect whole-room calorimetry to measure energy expenditure. Only one other study has used this method to assess yoga energy expenditure. \[10\] The other common method to measure energy expenditure is use of metabolic cart, which has been used in 11 other studies. \[6\] The use of whole-room calorimetry has the advantage of allowing the study participant to perform physical activities unencumbered from study apparatus such as a face mask. Our results provide a closer approximation to regular yoga practice outside of a research setting.

Recent studies have indicated that yoga is comparable to brisk walking in metabolic expenditure and physiological benefits. \[11,12\] Overall, our results are consistent with prior studies demonstrating that yoga movements are light-to-moderate intensity exercise. \[4–11\] Our study is the first to quantify and report results of a wide variety of yoga poses in standing, lying, and sitting positions. Higher metabolic costs of yoga occur primarily in the standing positions. Therefore, the energy expenditure of a yoga practice will vary based on the quantity of standing versus

**Table 3: Pearson correlations between yoga and walking**

| Walking | Yoga total |
|---------|------------|
| Walking | Standing | Lying | Sitting | Yoga total |
| Walk 2 mph | 0.570 | 0.735* | 0.836** | 0.714* |
| Pearson’s correlation | 0.085 | 0.015 | 0.003 | 0.020 |
| Significant (two-tailed) | | | | |
| Walk 3 mph | 0.718* | 0.571 | 0.813* | 0.760* |
| Pearson’s correlation | 0.019 | 0.085 | 0.004 | 0.011 |
| Significant (two-tailed) | | | | 0.820** |
| Walk total | | | | 0.004 |
| Pearson’s correlation | | | | |
| Significant (two-tailed) | | | | |

*Correlation is significant at the 0.05 level (two-tailed), **Correlation is significant at the 0.01 level (two-tailed)
sitting or lying poses. Our results also suggest that yoga’s physical intensity yoga could be titrated based on body orientation (standing, lying, and sitting) and selection of movement. We report consistent results with yoga being comparable to walking at 2–3 mph on a treadmill.

Specific yoga sequences such as sun salutation (surya namaskar) have higher metabolic expenditure accordingly to our results and other studies. Prior studies measuring sun salutations range from 2.9 to 7.4 metabolic equivalents.

Our study measured the average METS for sun salutations to be 2.4. It is not clear why the METS for sun salutations varies between studies, but indicates that energy expenditure from yoga may not be reliable based on specific sequences or poses.

Furthermore, our study shows that for women, the metabolic intensity of yoga is substantially lower than men while taking into account body mass, resting \( \text{VO}_2 \), and frequency of yoga practice. With conventional exercise, such as walking or running, there has been no significant difference in expended energy between men and women when adjusted for mass or fat-free mass. It is not clear why women in the study expended less energy than men. One possibility is that women perform the yoga differently than men based on unaccounted musculoskeletal or psychological factors. Given the low intensity yoga in general, women may benefit than men from the cardiovascular benefits of yoga as derived from \( \text{VO}_2 \).

Many people practice yoga not only for physical exercise but also for mental health benefits such as relaxation. These benefits may be gained with less intense yoga practice composed mostly in lying and sitting positions. Since a wide variety of yoga styles exist, individuals may choose a style that meets their health goals. Of note, yoga traditionally does not emphasize excessive physical exertion during practice. While the physical movements of yoga have become popular, stationary nonphysical practices such as deep breathing exercises and meditation are considered the ultimate goal of traditional expert practitioners.

**Limitations**

We sequenced yoga movements sequentially with 1-min rest between movements. Therefore, the distinct metabolic cost of individual yoga movements and variations should be interpreted with caution since latter movements may have higher energy due to prior movements. We performed the study to mimic normal yoga practices, but typical regular practices are not as long nor do they consist of as many interventions. The yoga protocol consisted of more yoga movements than typically performed in a single session which may have produced fatigue in individuals. We did try to approximate the number of repetitions, rest, and general sequence used in Viniyoga. Since yoga movements were sequenced serially, analyzes were performed in aggregate. It is difficult to separate the distinct metabolic cost of individual movements from our study design, and differences between variations of specific poses may not have been measurable. We selected only Viniyoga method, and other yoga styles may have different metabolic costs. However, we specifically chose this method since it uses movement with breathing, and so, it characterizes a central philosophy to yoga. Study participants were regular yoga practitioners, and yoga novices may have had different results. Our sample size included only 10 participants, which may limit the generalization of results to the general population and differences between genders. We did not account for variations in sleep, fluid intake, and menstrual cycle in females that may be important factors.

**Conclusion**

\( \text{VO}_2 \) during yoga varied among individuals and by body orientation of yoga poses. Being female accounted from a large amount of variation. When considering yoga as a form of aerobic exercise, sex, and body orientation of movements needs to be accounted.

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Conflicts of interest
There are no conflicts of interest.

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