©Journal of Sports Science and Medicine (2013) **12,** 571-578
http://www.jssm.org

Research article

The Association between Physical Activity and Sex-Specific Oxidative Stress in Older Adults

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Abstract

Oxidative stress increases with advancing age and is a mediator of several diseases including cancer, cardiovascular disease, and diabetes. Moreover, postmenopausal women have a lower estrogen concentration, which is associated with elevated oxidative stress. However, there is no definitive evidence regarding the relationship between daily physical activity and oxidative stress status in older adults, including postmenopausal women. Twenty-nine adults (age, 70.1 ± 1.0 years, mean ± SE; 12 women and 17 men) were examined in this cross-sectional study. Prior to blood collection, the participants were asked to wear a uniaxial accelerometer for 4 consecutive weeks to determine their level of physical activity. After a 48-h period of physical activity avoidance and a 10-h overnight fast, venous blood samples were obtained from each participant. Fasting plasma derivatives of reactive oxygen metabolites (d-ROMs) and malondialdehyde (MDA) concentrations of oxidative stress markers were negatively correlated with the amount of physical activity in women (d-ROMs; r = -0.708, p = 0.002) (MDA; r = -0.549, p = 0.028), but not in men. Fasting plasma biological antioxidant potential of antioxidant capacity marker was positively correlated with the amount of physical activity in women (BAP; r = 0.657, p = 0.006) (GSH; r = 0.549, p = 0.028), but not in men. Moreover, superoxide dismutase activity of antioxidant capacity marker was positively correlated with the amount of physical activity in men (r = 0.627, p = 0.039), but not in women. There were no associations between physical activity and other oxidative stress markers (reduced and oxidized glutathione, glutathione peroxidise, thioredoxin). These findings suggest that regular physical activity may have a protective effect against oxidative stress by increasing total antioxidant capacity, especially in postmenopausal women.

Key words: Aging, physical activity, oxidative stress, antioxidant capacity, sex.

Introduction

Reactive oxygen species (ROS) play an important role in the maintenance of homeostasis through immune function and cellular signals (Hekimi et al., 2011; Naik and Dixit, 2011). However, ROS can react with DNA, proteins, and lipids and play an important role in many physiological and pathophysiological conditions, such as cancer, atherosclerosis, and aging (Mecocci et al., 1999; Patel et al., 2011; Bjelakovic et al., 2007). Previous studies have shown that ROS and oxidative stress increase with age (Ji 1993; Kasapoglu and Ozben, 2001). Some studies have shown that aerobic exercise training decreases the level of oxidative stress markers, and increases enzymatic and non-enzymatic antioxidant capacity in middle-aged and elderly individuals (Fatouros et al., 2004, Takahashi et al., 2013). However, little is known about the effect of daily physical activity on oxidative stress and antioxidant capacity in older adults. Further research is needed to investigate the role of daily physical activity on oxidative stress markers.

Several researchers have reported different mechanisms for sex-related oxidative stress (Goldfarb et al., 2007; Bloomer and Fisher-Wellman, 2008). Women may be less susceptible to oxidative stress because of the antioxidant properties of estrogen (Kendall and Eston, 2002; Shwaery et al., 1997). Postmenopausal women do not experience the protective antioxidant benefits and anti-inflammatory effects of estrogen, and are therefore likely to show increased oxidative stress (Karolkiewicz et al., 2009; Krstevska et al., 2001). From the viewpoint of aging and postmenopausal aging, it is important to decrease oxidative stress by increasing physical activity. The purpose of this study was to examine the relationship of the amount of physical activity with the level of sex-specific oxidative stress markers in older adults.

Methods

Participants

Participants were recruited from the general population (i.e. none were trained athletes competing in sporting events but some were recreationally active) from 2 local communities (i.e. the cities of Tokorozawa and Iruma). To support health promotion in these communities, we encouraged all participants to enroll in this cross-sectional study if they met the recruitment criterion of having no difficulty in performing activities of daily living. However, 16 participants were excluded from data analysis (but not from providing feedback). The reasons for exclusion included taking lipid- and/or glucose-lowering medication, antioxidant supplementation, and having insufficient accelerometer wear time (see "Physical activity measurement" section below). Thus, data of 29 participants (17 women and 12 men aged 61-80) are presented here. The physical characteristics of the participants are shown in Table 1. This study was conducted according to

Received: 26 February 2013 / Accepted: 04 July 2013 / Published (online): 01 September 2013

the guidelines laid down in the Declaration of Helsinki and was approved by the ethics committees of Waseda University. Informed consent was obtained from all participants following a detailed description of the experiment.

Physical activity measurement

For the determination of physical activity levels, the participants were asked to wear a uniaxial accelerometer (Lifecorder-EX; Suzuken Co. Ltd., Nagoya, Japan) for 4 consecutive weeks prior to the measurements of anthropometry, arterial blood pressure and blood collection. A number of studies have reported that the Lifecorder-EX is considered as a validated accelerometer to evaluate and monitor the physical activity levels (Ayabe et al., 2013; Kumahara et al., 2004). The participants were contacted by phone at the beginning of each week for the assessment of adherence and any device-related problems. No participants reported any problems with the use of the accelerometer, and all the participants wore the accelerometer on each day during the data-collection period. Accelerometer data were collected from all the participants simultaneously, and any seasonality-related variation in the results was eliminated. The device determined the intensity of the activity (i.e. 11 levels: 0, 0.5, 1-9; 0 is the lowest-intensity activity; 9 is the highest-intensity activity) by measuring the magnitude and frequency of acceleration every 4 s. Data from participants who had worn the accelerometer for at least 10 h (600 min) a day for at least 4 weekdays and 1 weekend day (i.e. in total) were considered valid (Chen et al., 2009; Matthews et al., 2008). The main physical activity variable used in this study was the duration of moderate to vigorous physical activity (MVPA). MVPA was calculated on a daily basis and used to estimate weekly activity by calculating a weighted average of daily weekday and weekend activity (i.e. weekly MVPA = (average daily weekday MVPA × 5) + (average daily weekend MVPA × 2)). All minutes of recording with a total of ≥ 4 activity levels were classified as MVPA. The threshold of 4 activity levels was derived from a calibration study (Kumahara et al. 2004) and corresponded to approximately 3 metabolic equivalents. To establish whether the level of blood markers was associated with the amount of physical activity, we divided the participants into 2 groups. The active group included participants who performed MVPA of 150 min or more per week, because this amount of physical activity is the minimum expenditure recommended by current physical activity guidelines for health (Haskell et al. 2007); the inactive group included participants who performed MVPA of less than 150 min per week. We used questionnaires and face-to-face interviews to determine the true nature of the participants' long-term physical activity status before the monitoring period. No change was observed in the participants' daily activity habits during the monitoring period.

Anthropometry

Anthropometric variables were measured after the physical activity measurement (i.e, at week 4) for all participants. Body mass was measured to the nearest 0.1 kg using a digital scale (Inner Scan 50, Tanita Co., Japan). Height was measured to the nearest 0.1 cm using a wall-mounted stadiometer (YS-OA, As One Co., Japan). Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters. Waist circumference was measured to the nearest 0.1 cm at the level of the umbilicus using a flexible plastic tape.

Arterial blood pressure

Arterial blood pressure was measured after the physical activity measurement (i.e, at week 4) for all participants. Arterial blood pressure was measured in the right arm with a standard mercury sphygmomanometer (605P, Yagami Co. Ltd., Japan) while the participant was in a seated position. Participants were seated on a chair for 5 min before the measurements. Two measurements were taken at each time point and the mean of these values were recorded.

Blood collection and laboratory assays

In the present study, blood samples were collected after the physical activity measurement (i.e. at week 4) for all participants. Venous blood samples were taken from an antecubital vein after a 48-h period of physical activity avoidance and an overnight fast of at least 10 h. After collection, blood was centrifuged for 10 min at 3000 rpm to separate the plasma. All plasma samples were stored at -80°C until the day of assay.

The plasma concentrations of the derivatives of reactive oxygen metabolites (d-ROMs) were analyzed using the method described by Verde et al (2002) and Cornelli et al. The d-ROMs test provides a measure for the oxidative stress of blood samples by evaluating the level of reactive oxygen metabolites, in particular hydroperoxides. This assay is based on the capability of N,N-dimethyl-p-phenylenediamine (DMPD) to give a stable, colored solution when it is transformed into its radical cation ($DMPD^{+}$). The assay was performed in a 5-mL plastic tube by adding 20 µL of DMPD (final concentration 1 mM) and 10 µL of plasma sample to 2 mL of 0.1 M acetate buffer at pH 4.8. The formation of the colored DMPD radical cation was monitored by reading the absorbance at 505 nm. The amount of the colored DMPD radical cation is related to the oxidative stress of the plasma and can be expressed in terms of hydrogen peroxide equivalents, with 1 U.CARR (Carratelli unit) corresponding to 0.8 $mg \cdot L^{-1}$ hydrogen peroxide.

The plasma concentration of malondialdehyde (MDA) was measured with the assay kit from Cayman Chemicals (Cayman Chemicals, USA), using a modified spectrofluorimetric measurement of thiobarbituric acid reactive substances (TBARS). An aliquot of plasma (100 µL) was mixed with 100 µL of TBA-sodium dodecyl sulfate (SDS) and 4 mL of TBA acetic acid solution. The samples were incubated at 90°C for 1 h, cooled on ice for 10 min, and centrifuged for 10 min at 1,600 × *g* at 4°C. The absorbance of the supernatant was measured at 530 nm. A standard curve was constructed using MDA as a standard at 0, 0.625, 1.25, 2.5, 5, and 10 µM concentrations.

The biological antioxidant potential (BAP) test was

conducted using the Free Radical Analytical System (Diacron, Italy) according to the manufacturer's instructions. The BAP assay is a photometric test that determines the serum concentration of antioxidants capable of reducing the iron from the ferric to the ferrous form. A plasma aliquot (10 µL) was dissolved in 1 mL of colored solution obtained by mixing 50 µL of ferric ions ($FeCl_3$; ferric chloride) with a chromogenic substrate (a sulfur-derived compound). Following 5-min incubation, the intensity of the color change was assessed spectrophotometrically at 505 nm. The amount of reduced ferric ions was calculated and the BAP unit was expressed as $\mu mol \cdot L^{-1}$.

The concentration of plasma thioredoxin (TRX) (Immuno-Biological Laboratories Co., Ltd., Japan) was measured by enzyme-linked immunosorbent assay (ELISA) using a commercially available kit. The kit used in this study is a solid-phase sandwich ELISA using 2 high specific antibodies and tetra methyl benzidine (TMB) as a coloring agent (Chromogen). The coloring is proportional to the amount of human TRX-1.

Plasma concentrations of reduced and oxidized glutathione (GSH and GSSG, respectively), along with the activity of superoxide dismutase (SOD) and glutathione peroxidase (GPX), were measured using the assay kits from Cayman Chemicals.

To calculate the GSH concentration, the kit utilizes an optimized enzymatic recycling method based on glutathione reductase (GR). The sulfhydryl group of GSH reacts with the Elman's reagent [DTNB, (5,5-dithio-bis-2-(nitrobenzoic acid)] and produces a yellow-colored 5-thio-2-nitrobenzoic acid (TNB). The mixed disulfide between GSH and TNB (GSTNB), which is concomitantly produced, is reduced by GR to recycle the GSH and produce more TNB. The rate of TNB production is directly proportional to this recycling reaction, which is in turn directly proportional to the concentration of GSH. The absorbance of the sample was read at 450 nm. A standard curve was constructed using GSH as a standard at 0, 0.5, 1, 2, 4, 8, 12, 16 µM concentrations. The quantification of GSSG in the plasma, formed exclusively from GSH, is accomplished using 2-vinylpyridine.

To measure the SOD activity, the assay utilizes a tetrazolium salt that detects superoxide radicals generated by xanthine oxidase and hypoxanthine. An aliquot of plasma (10 µL) was mixed with 200 µL of the tetrazolium salt solution. The reaction in the samples was initiated by adding 20 µL of xanthine oxidase. The samples were incubated at 37°C for 20 min, and then the absorbance of the sample was read at 450 nm. A standard curve was constructed using SOD as a standard having 0, 0.025, 0.05, 0.1, 0.15, 0.2, 0.25 $U \cdot mL^{-1}$ activities. One unit is defined as the amount of enzyme needed to exhibit 50% dismutation of the superoxide radical.

To measure the GPX activity, the assay measures GPX activity indirectly through a reaction coupled with GR. An aliquot of plasma (20 µL) was mixed with 120 µL of assay buffer (50 mM Tris-HCl, 5 mM EDTA, pH 7.6) and 50 µL of Co-Substrate Mixture (lyophilized NAPDH powder, glutathione, and GR). The reaction in the sample was initiated by adding 20 µL of cumene hydroperoxide. The absorbance of the sample was read at 340 nm for 3 min to calculate the rate of the absorbance change. Under the conditions in which the GPX activity is the limiting factor, the rate of the absorbance change is directly proportional to the GPX activity.

Dietary assessments

To examine whether antioxidant vitamin intake influences oxidative stress markers, we administered diet recall questionnaires (i.e. data were collected from a previous week). Diet records were analysed using the computerised nutritional analysis system of the Food Frequency Questionnaire Based on Food Groups (Kenpakusha, Japan). Dietary assessments were conducted by a registered dietitian.

Statistical analysis

Data were analysed using Predictive Analytics Software (PASW) version 18.0 for Windows (SPSS Japan Inc., Tokyo, Japan). The Kolmogorov-Smirnov test was used to check for normal blood marker distribution. The distribution of these markers did not differ significantly from the norm. Student's t-test was used to compare differences between the men and women. Partial correlation was used to examine the relationship between the amount of physical activity and blood markers after adjustment for age as a confounding factor. Statistical significance was accepted at the 5% level. Results are presented as means ± standard error (SE)

Results

Physical characteristics

There were no differences in physical and physiological characteristics between men and women, with the exception of height and body mass (Table 1).

Physical activity and dietary intake

The amount of MVPA detected by the accelerometer was 177.0 ± 81.3 $min \cdot week^{-1}$ (range; 55.6–345.0 $min \cdot week^{-1}$). Analysis of the food survey revealed that antioxidant intake (Vitamin C, Vitamin E, and β-carotene) was not correlated with the level of oxidative stress markers (d-ROMs, MDA, GSSG, BAP, GSH, SOD, GPX, and TRX). Therefore, we did not adjust for dietary antioxidant

Table 1. Physical characteristics of the subjects. Data are means (±SE).

Variables	Men (n =12)	Women (n =17)	All (n = 29)
Age (years)	73.6 (1.1)	67.6 (1.1)	70.1 (1.0)
Height (m)	1.62 (.02)	1.53 (.01)	1.56 (.01)
Body mass (kg)	58.1 (1.5)	50.6 (1.9)	53.7 (1.4)
Body mass index ($kg \cdot m^{-2}$)	22.2 (.4)	21.8 (.7)	21.9 (.4)
Waist circumference (cm)	84.7 (1.0)	80.9 (2.3)	82.4 (1.4)
SBP (mm Hg)	128 (2)	126 (2)	127 (1)
DBP (mm Hg)	70 (1)	71 (1)	71 (1)

Table 2. Plasma and serum oxidative stress marker levels. Data are means (±SE).

Variables	Men (n =12)	Women (n =17)	All (n = 29)
d-ROMs (U.CARR)	288.1 (34.5)	444.2 (60.4) *	379.6 (40.3)
MDA (µM)	.801 (.08)	.902 (.124)	.861 (.103)
GSSG (mM)	.068 (.02)	.069 (.02)	.068 (.02)
BAP (µM)	2647.8 (175.2)	3140.9 (170.1)	2939.8 (130.0)
GSH (mM)	.772 (.15)	.770 (.13)	.771 (.14)
SOD (U/ml)	2.2 (.5)	2.1 (.3)	2.1 (0.3)
CAT (U/ml)	256.7 (28.1)	240.8 (18.5)	247.4 (15.7)
GPX (U/ml)	100.1 (6.0)	105.5 (2.7)	103.3 (2.9)
TRX (ng/ml)	38.2 (6.2)	63.2 (8.3)	53.6 (5.9)

dROMS, derivatives of reactive oxygen metabolites; MDA, malondialdehyde; GSSG, glutathione-S-S-Gulutathione; BAP, biological antioxidant potential; GSH, Gulutathione-SH; SOD, superoxide dismutase; GPX, glutathione peroxidise; TRX, thioredoxin.
* Significantly different from the mean value (unpaired Student's *t* test, $p < 0.05$).

vitamin intake as a confounding factor related to oxidative stress markers.

Physical activity and oxidative stress markers

Fasting plasma d-ROMs concentrations were negatively correlated with the amount of physical activity (r = -0.488, p = 0.008) (Figure 1a). In addition, plasma MDA concentrations were negatively correlated with the amount of physical activity (r = -0.399, p = 0.036) (Figure 1b). Plasma BAP concentrations were positively correlated with the amount of physical activity (BAP; r = 0.607, p = 0.001). Moreover, plasma d-ROMs concentrations tended to be negatively correlated with fasting plasma BAP concentrations (r = -0.320, p = 0.097). The amount of physical activity was not associated with the level of other oxidative stress markers (GSSG, GSH, SOD, GPX and TRX) (Figure 1d) (Table 3).

Fasting plasma d-ROMs concentrations tended to be lower in the active than inactive groups (490.9 ± 85.8 versus 311.6 ± 31.0 U.CARR, respectively, p = 0.072) (Figure2a). Fasting plasma BAP concentrations were significantly higher in the active than inactive groups (2499.2 ± 72.7 versus 3204.3 ± 177.6 µM, respectively, p = 0.001) (Figure 2b).

Physical activity and sex-specific oxidative stress markers

Plasma d-ROMs concentrations were significantly higher in women compared with men. Plasma BAP and TRX concentrations tended to be higher in women. MDA, GSH, GSSG concentration and SOD and GPX activity did not differ significantly between men and women (Table 2).

Plasma d-ROMs concentrations were negatively correlated with the amount of physical activity in women (r = -0.708, p = 0.002), but not in men (Figure 1a). Plasma

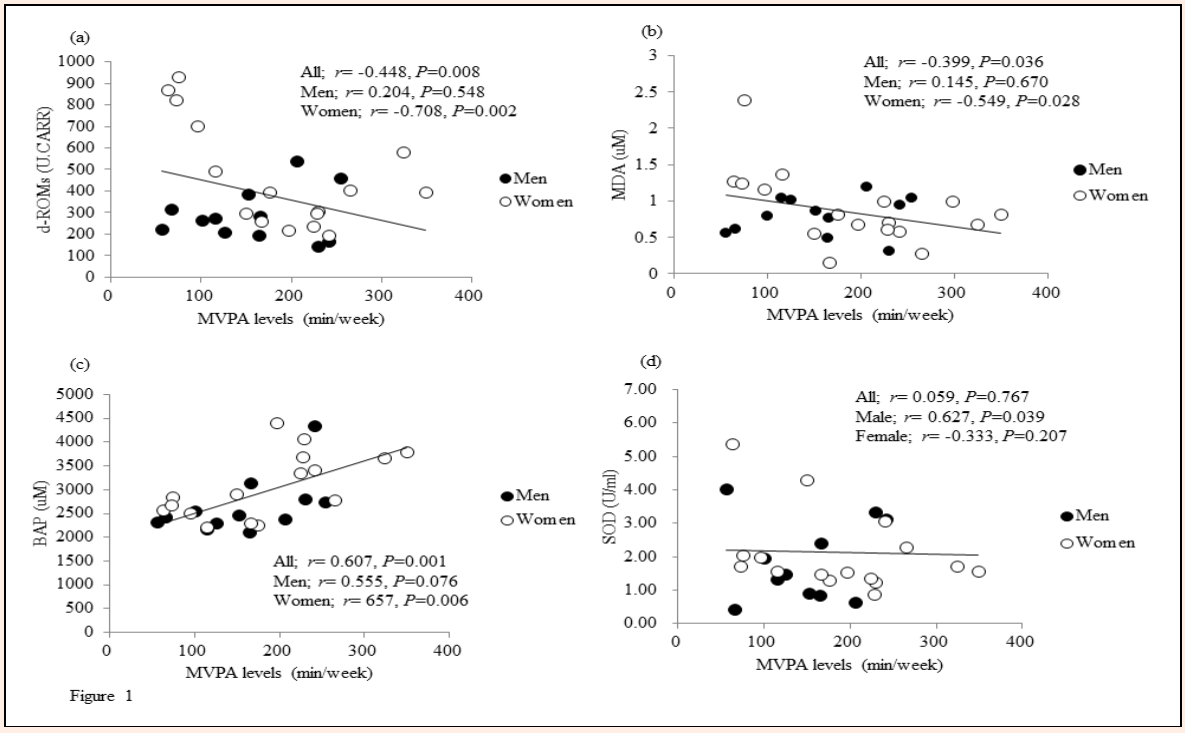

Figure 1. The relationship across all participants between moderate to vigorous physical activity (MVPA) levels and fasting plasma concentrations of derivatives of reactive oxygen metabolites (d-ROMs) (a), malondialdehyde (MDA) (b), biological antioxidant potential (BAP) (c), superoxide dismutase (SOD) (d). Sample sizes were as follows: men (n = 12) and women (n = 17).

Table 3. The correlations between the amount of moderate to vigorous physical activity (MVPA) and sex-specific blood markers.

Variables	Participants	*r* #	p
GSSG (mM)	Men	-.399	.225
	Women	.258	.334
	All	.045	.819
GSH (mM)	Men	-.282	.401
	Women	-.205	.445
	All	-.214	.274
GPX (U·ml^{-1})	Men	-.303	.365
	Women	-.429	.098
	All	-.334	.082
TRX (pg·ml^{-1})	Men	-.048	.902
	Women	.181	.518
	All	-.048	.747

Age adjusted Pearson's correlation coefficient. GSSG, glutathione-S-S-Gulutathione; GSH, Gulutathione-SH; GPX, glutathione peroxidise; TRX, thioredoxin.

MDA concentrations were negatively correlated with the amount of physical activity in women (r = -0.549, p = 0.028), but not in men (Figure 1b). Plasma BAP concentrations were positively correlated with the amount of physical activity in women (r = 0.657, p = 0.006), and a tendency for a positive correlation was observed in men (r = 0.555, p = 0.076) (Figure 1c). Moreover, SOD activity was positively correlated with the amount of physical activity in men (r = 0.627, p = 0.039), but not in women (Figure 1d). The amount of physical activity was not associated with the level of other oxidative stress markers (GSSG, GSH, GPX and TRX) in men or women (Table 3).

Discussion

In this study, we examined the relationships of the amount of daily physical activity with the level of oxidative stress markers in older adults. The main findings are that plasma concentrations of d-ROMs and MDA were negatively correlated with the amount of physical activity in women, and that plasma BAP concentrations were positively correlated with the amount of physical activity in both men and women. These findings indicate that daily physical activity may have a protective effect against oxidative stress by increasing total antioxidant capacity especially in postmenopausal women.

A number of studies have examined the effects of endurance training on markers of oxidative stress and antioxidant capacity (Fatouros et al., 2004; Takahashi et al., 2013; Traustadottir et al., 2012). These studies found that endurance training attenuated resting and exercise-induced oxidative stress, and increased protection against oxidative stress by increasing the efficiency of enzymatic and non-enzymatic antioxidant defence systems, suggesting training-induced adaptations of oxidative stress. However, few studies are available regarding the relationship between daily physical activity status and oxidative stress status in older adults. In the present study, plasma concentrations of d-ROMs and MDA were negatively correlated with the amount of daily physical activity. Other studies found that the concentrations of oxidative stress markers increase with aging and increase the risk of developing various diseases such as cancer, cardiovascular disease and metabolic syndrome (Ferrucci et al., 2005; Ji, 1993). In addition, the usefulness of d-ROMs as an oxidative stress marker has been demonstrated in several studies, suggesting their association with these diseases (Abramson et al., 2005; Cornelli et al., 2001; Fukui et al., 2011). Thus, it is worth noting that plasma concentrations of d-ROMs may be decreased by increasing daily physical activity in older adults. Moreover, plasma oxidised low-density lipoprotein, a risk marker for cardiovascular disease, has been reported to be negatively correlated with

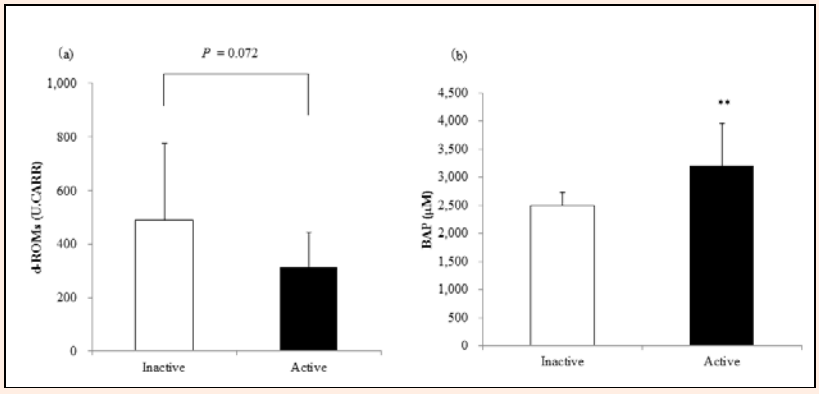

Figure 2. Plasma derivatives of reactive oxygen metabolites (d-ROMs) (a) and biological antioxidant potential (BAP) (b) concentrations in the active (n = 11) and inactive (n = 18) groups. Data are means ± SE. ** Significantly different from the inactive group (unpaired Student's *t* test, p < 0.01).

the amount of physical activity (Park et al., 2011). Lowering of oxidised low-density lipoprotein concentrations is essential for better maintenance of the pro-oxidant / antioxidant balance. Our findings imply that physical activity is important for the reduction of oxidative stress and the potential risk of atherosclerosis and cardiovascular disease in older adults.

One study has reported that physically active older adults have a lower exercise-induced oxidative stress than older adults with a lower level of physical activity (Meijer et al., 2002). On the other hand, this study was not measured the blood antioxidant capacity markers. We found positive associations between the amount of physical activity and plasma BAP concentrations. Moreover, plasma concentrations of d-ROMs tended to be negatively correlated with plasma BAP concentrations. These results indicate that regular physical activity plays a protective role against oxidative stress by increasing antioxidant capacity.

In relation to the antioxidant defence system, a previous study has shown that habitual physical activity and aerobic capacity have no influence on the resting antioxidant capacity in elderly men (Kostka et al., 2000). One reason of inconsistent results is that they evaluated the physical activity by a questionnaire. In addition, the subjects of the previous study were only older men (Kostka et al., 2000). Our results indicate that sex differences affect the alteration of oxidative stress markers induced by daily physical activity.

In this study, active older adults who adhere to physical activity guidelines for health (i.e. $\geq$ 150 min·week^{-1}) (Haskell et al., 2007) tend to have lower concentrations of d-ROMs and significantly higher BAP concentrations than do those who do not adhere to these guidelines. Our results suggest that adherence to physical activity guidelines for health (i.e. $\geq$ 150 min·week^{-1}) reduces the level of oxidative stress markers. Dietary antioxidant vitamin intake might influence the level of oxidative stress markers. In the present study, antioxidant intake (i.e. vitamin C, vitamin E, and β-carotene) was not correlated with the level of oxidative stress markers. These findings suggest that regular physical activity increases endogenous antioxidants, and physical activity thus induces positive adaptations in the antioxidant defence system without influencing dietary antioxidant intake.

Some studies have shown that enzymatic antioxidant defence systems such as SOD and GPX activity increase when people engage in exercise training (Fatouros et al., 2004; Takahashi et al., 2013). Moreover, a previous study also has reported that exercise training increased TRX levels in older adults (Takahashi et al., 2013). TRX and GSH play an essential role in cellular function and protection by limiting oxidative stress directly via its antioxidant effects (Lappalainen et al., 2009; Nordberg and Arner, 2001). In the present study, there were no associations between physical activity and these antioxidant capacity markers. This discrepancy may be due to differences in the duration and intensity of exercise. Our study assessed the daily physical activity status of older adults for a long-term period. Most previous studies have been conducted under laboratory conditions with participants performing exercise as part of the experimental conditions for a designated period of time. Therefore, it may be important to consider daily physical activity status when evaluating antioxidant capacity.

Sex is known to influence oxidative stress status (Bloomer and Fisher-Wellman, 2008). Goldfarb et al. have reported reduced glutathione (GSH) levels and α-tocopherol were higher in women than in men, respectively (Goldfarb et al., 2007). In our study, plasma BAP and TRX concentrations tended to be higher in women than in men. Women have a higher estrogen concentration than men do, and this may affect the oxidative stress defence system because of the antioxidant capacity of estrogen. Other studies have indicated that the level of markers of lipid peroxidation and protein and DNA oxidation were lower in women than in men (Nakano et al., 2003). Conversely, postmenopausal women have a lower estrogen concentration, which is associated with increased oxidative stress (Karolkiewicz et al., 2009). In our study, plasma concentrations of d-ROMs were significantly higher in women than in men. These results indicate that the status of sex-related oxidative stress markers varies according to age. Few studies have been reported that the protective effect of physical activity against oxidative stress in older adult, especially in comparison with different sex. In this point, we observed that plasma concentrations of d-ROMs and MDA were negatively correlated with the amount of physical activity in women but not in men. In addition, plasma BAP concentrations were positively correlated with the amount of physical activity in women. Thus, our results suggest that oxidative stress status is influenced by daily physical activity, especially in postmenopausal women.

Conclusion

In conclusion, we have demonstrated that daily physical activity may have a protective effect against oxidative stress by increasing antioxidant capacity, especially in postmenopausal women.

Acknowledgments

This study was supported by grants from the Ministry of Education, Culture, Sports Science and Technology of Japan, the Grant-in-Aid for the Global COE program "Sport Science for the Promotion of Active Life" (2010-2011) (to MM, YN, SS, KS), the Health Promotion Foundation (to MM, YN, SS, KS) and the Japan Health Foundation for the Prevention of Chronic Diseases and the Improvement of Quality of Life of Patients (to MM, YN, SS, KS). This paper is also a part of the outcome of research performed under a Waseda University Grant for Special Research Projects (to KS) (Project number: 2009A-506). All authors declare that they have no conflict of interest.

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Key points

- It is important to consider daily physical activity status when evaluating antioxidant capacity.
- Sex differences affect the alteration of oxidative stress markers induced by daily physical activity.
- Regular physical activity may have a protective effect against oxidative stress by increasing total antioxidant capacity, especially in postmenopausal women.

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