Journal of Aging and Physical Activity, 2016, 24, 399-406
http://dx.doi.org/10.1123/japa.2015-0005

Human Kinetics
ORIGINAL RESEARCH

Effects of Pilates Exercise on Salivary Secretory Immunoglobulin A Levels in Older Women

Yoonyoung Hwang, Jonghoon Park, and Kiwon Lim

We examined the effects of a Pilates exercise program on the mucosal immune function in older women. The study population comprised 12 older women who were divided into a Pilates group (PG, $n = 6$) and a control group (CG, $n = 6$). Saliva samples were obtained from both groups before and after the experimental period for salivary secretory immunoglobulin A level measurement. In addition, acute high-intensity exercises were performed before and after the three-month Pilates exercise program. After three months, salivary flow was significantly higher in the PG than in the CG. After the acute high-intensity exercises were performed following the three-month Pilates exercise program, the salivary flow rate was significantly higher at all time points. The S-IgA secretion rate significantly increased 30 min after acute high-intensity exercise performed following the three-month Pilates exercise program. This study suggests that regular participation in a moderate-intensity Pilates exercise program can increase salivary flow rate and S-IgA secretion in older women.

Keywords: Pilates exercise, salivary flow rate, salivary IgA, older women

The proportion of older adults is rapidly increasing in South Korea (Statistics Korea, 2011). This trend is also noted in other Asian countries (UN, 2012). In addition to aging, a lack of daily physical activity leads to reduced physical abilities and a decline in immune function. Changes in immune function seen in older adults are associated with a variety of diseases related to aging such as osteoporosis, sarcopenia, and cardiovascular disorders (Hortobágyi et al., 1995; Cheitlin, 2003). Respiratory disorders, such as upper respiratory tract infections (URTIs), can become severe in older adults with immune dysfunction, and in postmenopausal women, reduced estrogen production can further accelerate the age-related severity of URTIs (Bruunsgaard & Pedersen, 2000; Nieman et al., 1993). The risk of URTI may decrease with moderate-intensity exercise; however, it may increase with high-intensity exercise (Akimoto, et al., 2003), which is recommended for prevention of osteoporosis in postmenopausal women (Sloan, Engels, Fahlman, Yarandi & Davis, 2013).

Salivary secretory immunoglobulin A (S-IgA) is an immunoglobulin secreted by the salivary glands that is known to play an important role in the human mucosal immune system (Sloan, Engels, Fahlman, Yarandi & Davis, 2013). It can decrease with increasing age (Miletic, Schiffman, Miletic & Sattely-Miller, 1996). In previous studies, aging exacerbated immune system activity and reduced estrogen and S-IgA levels, which increased the risk of URTI after menopause in middle-aged women (Klentrou, Cieslak, MacNeil, Vintinner, & Plyley, 2002; Sloan, Engels, Fahlman, Yarandi, & Davis, 2013). Some studies have shown that exercising with walking is associated with increased S-IgA secretion in older adults (Nieman et al., 1993; Sloan, Engels, Fahlman, Yarandi & Davis, 2013). Moreover, the S-IgA secretion rate has been shown to increase in older adults after three months of moderate-intensity muscle strength exercises (Sakamoto et al., 2005). In contrast, high-intensity exercise decreases immune function (Neves et al., 2009). Thus, appropriate exercise, such as moderate-intensity activity, is considered to improve immune function (Akimoto et al., 2003; Sakamoto et al., 2005).

Recently, Pilates exercise, which is a combination of muscle strengthening, lengthening, and breathing, has become popular because of its effectiveness at increasing trunk muscle strength and restoring trunk flexibility in older adults (Laurent, 2001; Sutton-Tyrell et al., 2005). Muscle weakness is closely related to poor cardiorespiratory function (Al Snih, Markides, Ray, Ostir, & Goodwin, 2002; Sébastien, Marie-Eve, Marie-Eve, Mylène & Antony, 2012; Newman et al., 2006), and trunk flexibility has been linked to lung function (Laurent et al., 2001). In addition, Pilates exercise may increase oxygen and carbon dioxide exchange by improving thoracic movement, leading to more efficient cardiopulmonary respiration. The lung is very important for providing immunologic defense, as it uses adaptive immune response to inhaled antigens (Lowery, Brubaker, Kuhlmann, & Kovacs, 2013). Therefore, Pilates exercise may enhance immune function in older adults. However, to our knowledge, there are few data on the effect of Pilates on S-IgA levels in older adults.

Accordingly, the purpose of this study was to examine the effects of a Pilates exercise program on mucosal immune function in postmenopausal older women. In addition, we observed whether the mucosal immune function could change during acute high-intensity exercise after three months of Pilates exercise.

Methods

Subjects

The study population comprised 12 older women who were divided into a Pilates group (PG, $n = 6$) that participated in a Pilates exercise program and a control group (CG, $n = 6$) that did not participate in an exercise program. Finally, we analyzed S-IgA concentration using six subjects in each group because three subjects (two in the PG and one in the CG) failed the aerobic capacity/graded exercise test. Subjects were recruited by the prevention center of diabetes in Namyangju City, Gyeonggi Province. The subjects had no symptoms of a cold, allergies, or acute infection. They had not undergone an operation related to immune function and were not being treated for any illness related to immune function. Before

Hwang and Lim are with the Department of Physical Education, Konkuk University, Seoul, Korea. Park is with the Department of Physical Education, Korea University, Seoul, Korea. Address author correspondence to Kiwon Lim at exercise@konkuk.ac.kr.

testing, the subjects were given a detailed explanation of the risks and benefits of participation in the study before providing written informed consent. The study was approved by the Konkuk University Human Investigation Committee. The physical characteristics of the study subjects are shown in Table 1.

Study Design

A Pilates exercise program was performed for three months. Before and after the program, saliva samples were obtained from subjects between 9 and 10 a.m. after no exercise for 12 hr and resting in a sitting position for at least 15 min. In addition, acute high-intensity exercise was performed before and after the three-month Pilates exercise program, and saliva samples were obtained immediately after exercise and at 30 and 60 min after exercise.

Questionnaire

A questionnaire was administered to each subject individually in a quiet room. The researcher reviewed each questionnaire after completion to find omissions or errors. We used the questionnaire with minor modifications.

Pilates Exercise Program

The experiment group (PG) carried out the program for 12 weeks (three days per week, 50 min per session). Regarding Pilates mat work (Table 2), the beginner level exercised on days that did not follow each other. The intensity of the exercises was 40% of the target heart rate (THR) at the beginning and was progressively increased to 60% of the THR by the end of the study. The THR was calculated using the Karvonen method (Robergs & Langwehr, 2002). The intensity of the exercises was measured at the end of each work out. The participants were shown how to measure their heart rate and calculate the necessary work load. The measurements were taken at the same time by the participants. Background music with a slow rhythm was provided throughout the study to motivate the participants.

Aerobic Capacity/Graded Exercise Test

The subjects performed a graded exercise test for the assessment of aerobic power ($\dot{V}o_{2max}$) before and after the 12-week Pilates exercise intervention. We used the protocol employed by Åstrand with some modifications (Shindo, Kumagai, & Tanaka, 1987). Twelve older female subjects performed the test on an electronically braked cycle ergometer (Excalibur Sport, Lode, The Netherlands). During the test, all subjects performed a warm-up consisting of 2 min at 50 rpm with 0 kg. Thereafter, all subjects performed a trial consisting of 50 rpm with 50 W for a 6-min single-stage protocol. If HR was < 130 bpm at the end of the exercise session, the workload was increased to 60 W at 60 rpm for 6 more minutes. During exercise, the HR was measured using a short-range telemetry system (Sports Tester 3000, Polar Electro, Kempele, Finland) to determine exercise intensity. The exercise intensity was determined in accordance with and set to > 80% maximum HR, which averaged approximately 120 beats/min.

Table 1 Characteristics of Subjects

	CG (*n* = 6)	PG (*n* = 6)	*p*
Age (yrs)	68.3± 2.8	64.5 ± 5.6	.180
Height (cm)	155± 3.2	156 ± 2.8	.588
Weight (kg)	55.3 ± 4.5	59.5 ± 5.5	.266
BMI (kg/m^2)	23.0 ± 1.0	24.5 ± 2.8	.163

Note. CG = control group; PG = Pilates group. Values are mean ± *SE*

Saliva Collection

Saliva samples were collected in 10-ml tubes. The participants had been instructed not to consume food or drink for at least 3 hr before saliva collection. The acute exercise was always performed between 9and 10 a.m. To measure salivary flow rate, saliva was collected in a tube for 15 min. The samples were centrifuged for 15 min at 3,000 rpm and stored at –80° until analyzed.

S-IgA Assays

S-IgA concentrations were measured by enzyme-linked immunosorbent assay (ELISA, Salimetrics, State College, PA USA). All samples were assayed in duplicate. The interassay and intra-assay coefficients of the variation of the method, based on the analysis of kit duplicate samples, were 1.97% and 2.88%, respectively. The S-IgA secretion rate was calculated by multiplying the absolute S-IgA concentration (mg/ml) by the saliva flow rate (ml/min), which was calculated by dividing the total volume of saliva obtained in each sample (ml) by the time taken to produce the saliva sample (minutes) (Akimoto et al., 2003).

Statistical Analysis

One-way and two way analyses of variance were used to test for statistically significant differences between the groups. Statistical comparisons of the saliva flow rate, S-IgA concentration, and S-IgA secretion rate between the two groups over time were performed using two-way ANOVA. In addition, a Tukey post hoc test was used to compare saliva flow rates, S-IgA concentrations, and S-IgA secretion rates between the two groups at each time point. The experimental values are expressed as mean ± *SE*. Statistical significance was defined as $p < .05$. All statistical analyses were carried out using *SPSS* 20.0 software (IBM Corp., Armonk, NY, USA).

Results

Physical Characteristics

The physical characteristics of the subjects are shown in Table 1. Age, height, weight, and BMI did not differ between the groups.

Questionnaire on Respiratory Disease and Cold

A questionnaire related to respiratory disease and colds was given after completion of the three-month exercise program. During the three months, none of the subjects experienced any respiratory-related diseases or colds.

Mucosal Immune Function Before and After the Three-Month Pilates Exercise Program

Exercise intensity was measured during the three-month Pilates program and was 45% of the maximum HR at eight weeks and 61% of the maximum HR at three months (Table 2). No significant differences were found in salivary flow rate, absolute S-IgA concentration, or S-IgA secretion rate between the groups before the program. After the program, salivary flow was significantly higher in the PG than in the CG, but there was no significant difference in absolute S-IgA concentration or S-IgA secretion rate. Two-way

Table 2 Pilates Exercise Program

Time of Exercise	Contents	Program Levels	% HR max
Warm-up (5 min)	1. Breathing 5 reps		
	2. Hip release: 3 reps		
	3. Supine spinal: 4 reps		
	4. Arm circles: 5 reps		
Main exercise (40 min)	1. The hundred	Beginner (1–4 weeks): 8 reps, 2 sets	
	2. Roll up preparation		
	3. Rolling like a ball		
	4. Swimming		
	5. Obliques		
	6. Spine twist		
	7. Spine stretch forward		
	1. Hip release	Intermediate (5–8 weeks): 8 reps, 3 sets	
	2. Single leg circles		
	3. Double leg circles		
	4. The rolling like a ball		
	5. Side bend		
	6. Spine stretch forward		
	7. Side leg series		(8 wks)—% HR max 45 ± 6.3
	1. Hundred	Advanced (9–12 weeks): 10 reps, 3 sets	
	2. Hip release		
	3. Single-leg circles		
	4. Rolling like a ball		
	5. Swimming		
	6. Side bend		
	7. Spine stretch forward		
	8. Side leg series		(12 wks)—% HR max 61.2 ± 8.5
Cool-down (5 min)	1. Head nods: 4 reps		
	2. Hip rolls: 5 reps		
	3. Breast stroke prep: 3 reps		
	4. Cat stretch: 5 reps		

ANOVA analysis showed a significant interaction effect of time and group in salivary flow rate (Figure 1a).

Mucosal Immune Function After Acute High-Intensity Exercise Before and After the Three-Month Pilates Exercise Program

Salivary Flow Rate. Before participation in the three-month Pilates exercise program, there were no differences in salivary flow rate before and after acute high-intensity exercise between the groups at all time points (Figure 2a). Conversely, after the program, salivary flow rate was significantly higher before and after acute high-intensity exercise at all time points in the PG than in the CG (Figure 2b). Two-way ANOVA analysis showed a significant time effect in salivary flow rate before and after the acute high-intensity exercise both before and after the three-month Pilates exercise program (Figure 2a–b). A significant group effect was observed in the salivary flow rate after the acute high-intensity exercise only after the Pilates program (Figure 2b).

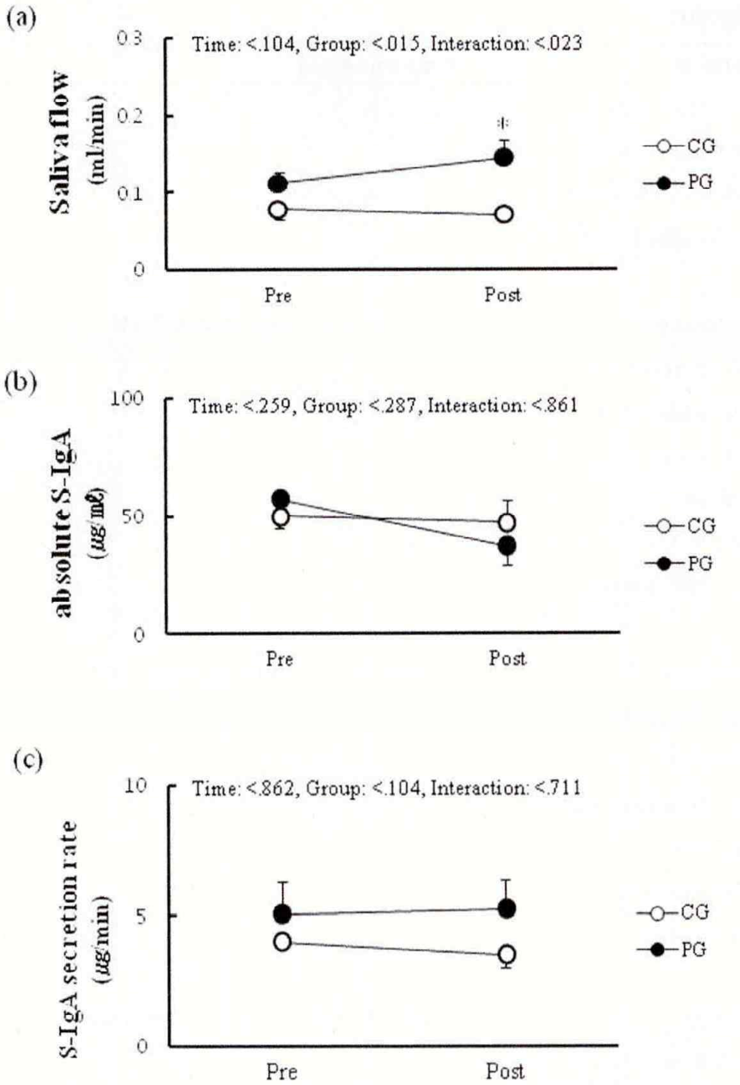

Figure 1 — Mucosal immune function before and after the three-month Pilates exercise program: (a) saliva flow (ml/min); (b) S-IgA concentration (μg/ml); (c) S-IgA secretion rate (μg/min). CG = control group; PG = Pilates group. Significant difference is indicated by $^*p < .05$; values are mean ± *SE*.

Absolute S-IgA Concentration. There were no differences in absolute S-IgA concentrations between the groups at all time points before and after high-intensity exercise performed before the three-month Pilates exercise program (Figure 3a). After the program, the absolute S-IgA concentration tended to increase after acute high-intensity exercise. This level was sustained 30 min after acute exercise in the PG, but decreased 30 min after acute exercise in the CG. However, there were no significant differences in absolute S-IgA concentration after the program (Figure 3b). Two-way ANOVA analysis showed a significant time effect in absolute S-IgA concentrations before and after acute high-intensity exercise both before and after the program (Figure 3a–b).

S-IgA Secretion Rate. There were no differences in S-IgA secretion between the groups at all time points before and after high-intensity exercises performed before the three-month Pilates exercise program (Figure 4a). Conversely, after the program, the S-IgA secretion rate tended to increase in the PG after acute high-intensity exercise, but this increase was not seen in the CG (Figure 4b). In particular, the S-IgA secretion rate was significantly higher at 30 min after acute high-intensity exercise in the PG than in the CG (Figure 4b). Two-way ANOVA analysis showed a significant group effect in the S-IgA secretion rate before and after acute high-intensity exercise both before and after the three-month Pilates exercise program (Figure 4a–b).

Discussion

The main finding in the current study was that the resting salivary flow rate in older women significantly increased after the three-month Pilates exercise program, whereas the S-IgA secretion rate did not change. Furthermore, the salivary flow rate was significantly higher at all time points after acute high-intensity exercise following the Pilates exercise program, although it did not differ between groups before starting the program. In particular, the S-IgA secretion rate was significantly higher 30 min after acute high-intensity exercise in the PG than in the CG. To our knowledge, this is the first study investigating the effect of the Pilates on mucosal immune function in older adults.

We found that the resting salivary flow rate in older women significantly increased after the Pilates exercise program, whereas the resting S-IgA secretion rate remained unchanged. The lack of difference in the resting S-IgA secretion rate as a result of the

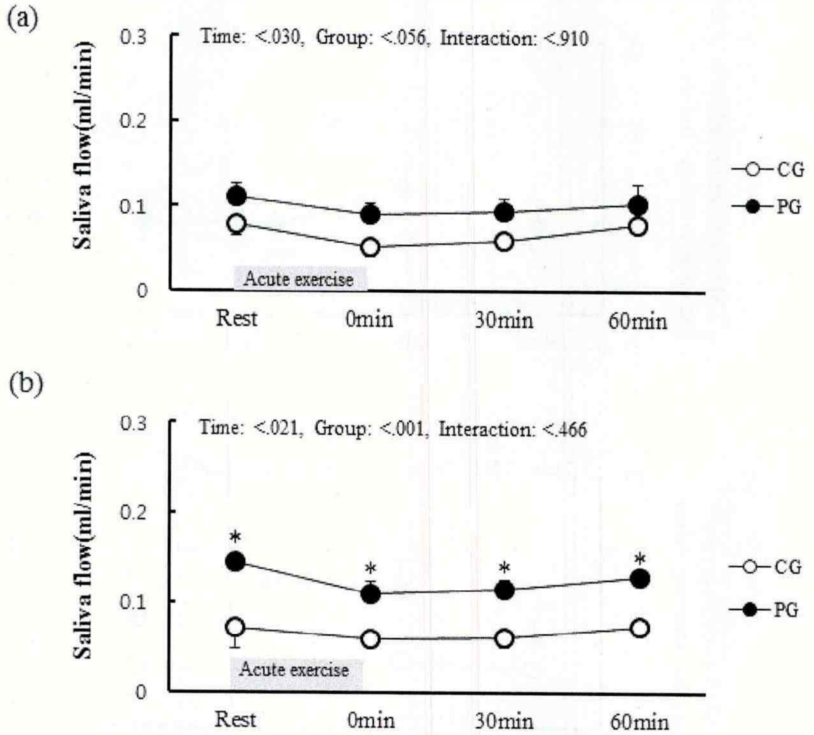

Figure 2 — Salivary flow rate (ml/min) after acute high-intensity exercise performed (a) before and (b) after the three-month Pilates exercise program. CG = control group; PG = Pilates group. Significant difference is indicated by $*p < .05$; values are mean ± *SE*.

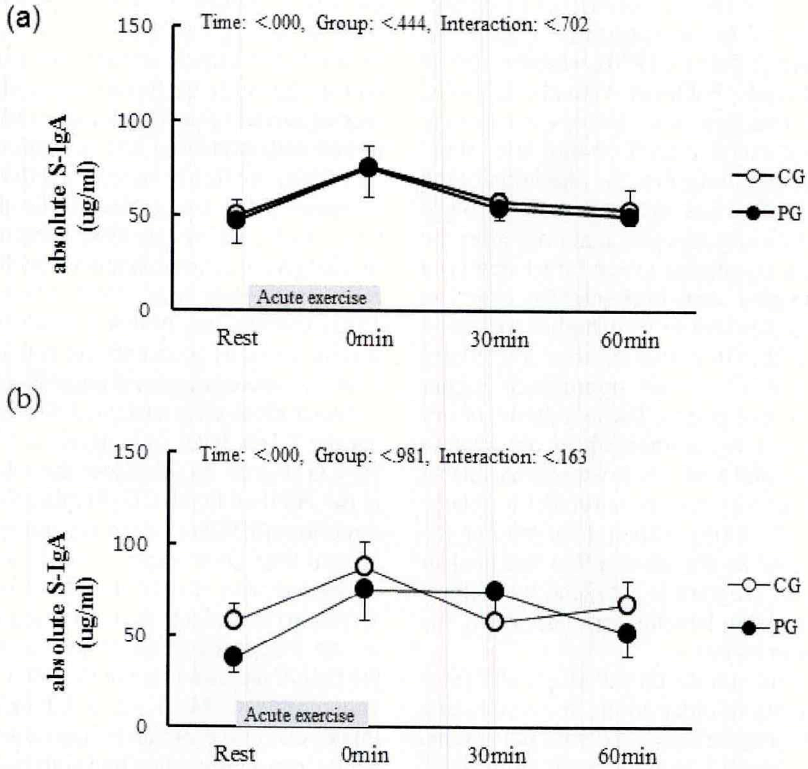

Figure 3 — Absolute S-IgA concentration (µg/ml) after acute high-intensity exercise performed (a) before and (b) after the three-month Pilates exercise program. CG = control group; PG = Pilates group; values are mean ± *SE*.

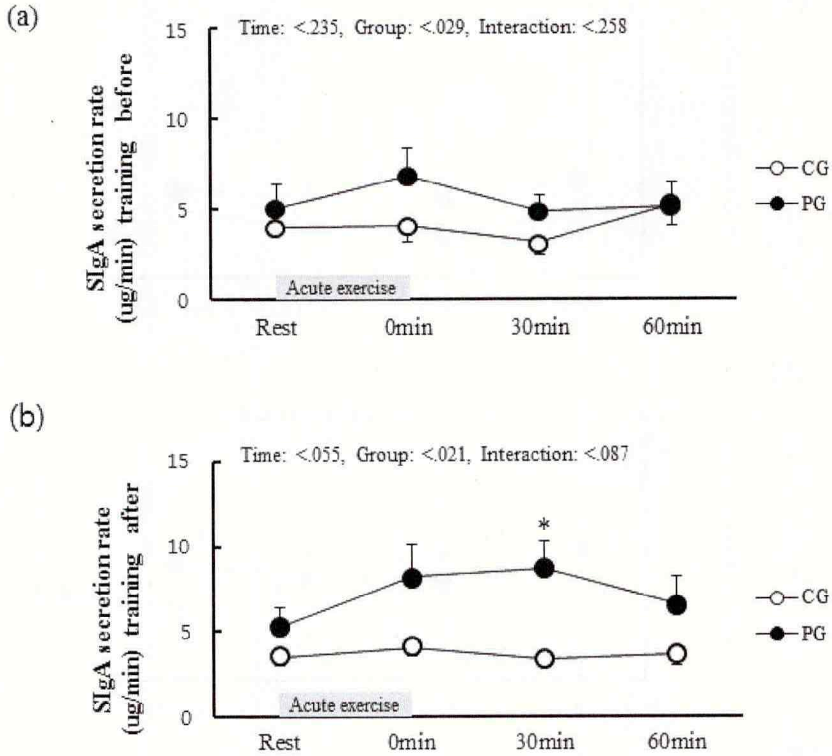

Figure 4 — S-IgA secretion rate (μg/min) after acute high-intensity exercise performed (a) before and (b) after the three-month Pilates exercise program. CG = control group; PG = Pilates group. Significant difference is indicated by $^*p < .05$; values are mean ± *SE*.

Pilates exercise program may be explained by the tendency of the resting S-IgA concentration to decrease through the Pilates exercise program (Figure 1b). Findings have shown that low- or moderate-intensity exercise does not affect S-IgA concentration (Sakamoto et al., 2005) or decrease it (Tharp & Barnes, 1990), whereas intense exercise increases it (Sloan, Engels, Fahlman, Yarandi, & Davis, 2013). We also found that saliva flow was decreased by acute exercise and returned to its pre-exercise level 60 min after acute exercise (Figure 2a–b). This finding indicates that alteration of the saliva flow caused by acute exercise was similar between groups. On the other hand, our results clearly revealed that only after the Pilates exercise program was a significant group effect observed in salivary flow rate before and after acute high-intensity exercise, showing that the rate for the PG was significantly higher compared with that for the CG (Figure 2b). In addition, after the Pilates exercise program, the salivary flow rate was significantly higher in the PG than in the CG at all time points. The symptoms of dry mouth and reduced salivary flow have commonly been observed in older adults (Pistilli et al., 2002), and evidence is accumulating that suggests that regular physical activity may be sufficient to reduce these symptoms (Sakamoto et al., 2005). Although, at present, the underlying mechanism of increased resting salivary flow rate in older women after the Pilates exercise program is not clear, we suggest that Pilates exercise may have strong benefits for maintaining the normal functioning of the immune system.

Although there have been no studies on the effect of Pilates exercise on the mucosal immunity of older adults, the results of a study by Sakamoto et al. (2005) can be compared with our results. In the Sakamoto et al. study, older adults underwent an exercise program for fall prevention. The exercise program consisted of 10 strength-training exercises of low to moderate intensity (average 3.1 metabolic equivalents). It was observed that resting S-IgA secretion rate increased after the three-month exercise program. However, it did not change after the three-month Pilates exercise program in our study (Figure 1c). One explanation for the lack of change in the resting S-IgA secretion rate in our study may be the difference in amount of muscle strength training in our study compared with that in the study by Sakamoto et al.. Our Pilates exercise, which was of moderate-level intensity (40–60% of maximum HR), was mixed with stretching and strength training.

Many studies have reported that acute high-intensity exercise decreases S-IgA concentration (Pistilli et al., 2002; Tomasi, Trudeau, Czerwinski, & Erredge, 1982), whereas some studies have reported that S-IgA concentration remain unchanged following high-intensity exercise (Blannin et al., 1998; MacKinnon, Chick, Van, & Tomasi, 1987). Our two-way ANOVA results showed that S-IgA concentration was increased by acute exercise both before and after the three-month Pilates exercise program (Figure 3a–b). After the program, the S-IgA concentrations were sustained 30 min after acute exercise in the PG, but the S-IgA level soon decreased 30 min after acute exercise in the CG (Figure 3b). Because the salivary flow rate was also higher in the PG than in the CG 30 min after acute exercise following the three-month Pilates exercise program, the S-IgA secretion rate 30 min after acute exercise might sustain a higher level in the PG compared with that in the CG. Consequently, the higher S-IgA secretion rate reflects the total amount of immunoglobulin available on the mucosal surface (MacKinnon & Jenkins, 1993). Because the S-IgA secretion rate in the older subjects was lower than in the young subjects (MacKinnon & Jenkins; 1993), it is possible that the Pilates exercise program reduces susceptibility to infections in older adults, especially when high-intensity physical activity is needed.

To evaluate the effect of exercise on a pathogenic virus infection (cold virus), we administered a questionnaire to all subjects. However, none of the subjects had an infection. We hypothesize that our experimental period was too short to examine the effect of Pilates exercise on susceptibility to a pathogenic virus infection. Furthermore, seasonal factors may have contributed to the lack of virus infection because the experiment was conducted between April and June rather than during the winter season.

Unexpectedly, we found a significant group effect in the S-IgA secretion rate before and after acute exercise even before the Pilates exercise program (Figure 4a). Specifically, the S-IgA secretion rate was higher in the PG than in the CG just 30 min after acute exercise even before the program. From this result, we cautiously assumed that the PG subjects performed more enthusiastically during the acute exercise trial before the Pilates exercise program. We should have conducted the acute exercise trial before subject allocation to the PG and the CG. This was a limitation of our study. However, our statistical analysis by post hoc testing showed that salivary flow rate was significantly higher in the PG than in the CG before and after acute high-intensity exercise at all time points after the Pilates exercise program (Figure 2-b), but this result was not observed before the program (Figure 2-a). Another limitation was that we did not provide direct measurements of cardiorespiratory or thoracic function. Pilates exercise has been recommended as a therapeutic strategy in sport rehabilitation. Therefore, further studies in this area will provide crucial insights into the development of a practical and powerful nonpharmacological therapeutic strategy that can be applied at various stages of cardiovascular or respiratory disease. For this reason, the effect of Pilates exercise on cardiorespiratory or thoracic function should be clarified in future studies.

Conclusion

This study suggests that participation in a moderate-intensity Pilates exercise program can increase the resting salivary flow rate in older women. Furthermore, a Pilates exercise program can increase the S-IgA secretion rate when needed during high-intensity physical activity. Pilates exercise, which can be performed safely by older people, could be an option for improving immune function in older women.

Acknowledgments

This study was supported by Konkuk University in 2014.

References

Akimoto, T., Kumai, Y., Akama, T., Hayashi, E., Murakami, H., Soma, R., . . . Kono, I. (2003). Effects of 12 months of exercise training on salivary secretory IgA levels in elderly subjects. *British Journal of Sports Medicine, 37,* 76–79. PubMed doi:10.1136/bjsm.37.1.76

Al Snih, S., Markides, K.S., Ray, L., Ostir, G.V., & Goodwin, J.S. (2002). Handgrip strength and mortality in older Mexican Americans. *Journal of the American Geriatrics Society, 50*(7), 1250–1256. PubMed doi:10.1046/j.1532-5415.2002.50312.x

Blannin, A.K., Robson, P.J., Walsh, N.P., Clark, A.M., Glennon, L., & Gleeson, M. (1998). The effect of exercising to exhaustion at different intensities on saliva immunoglobulin A protein and electrolyte secretion. *International Journal of Sports Medicine, 19*(8), 547–552. PubMed doi:10.1055/s-2007-971958

Bruunsgaard, H., & Pedersen, B.K. (2000). Special feature for the Olympics: Effects of exercise on the immune system: effects of exercise on the immune system in the elderly population. *Immunology and Cell Biology, 78,* 523–531. PubMed doi:10.1111/j.1440-1711.2000.t01-14-.x

Cheitlin, M.D. (2003). Cardiovascular physiology-changes with aging. *The American Journal of Geriatric Cardiology, 12*(1), 9–13. PubMed

Hortobágyi, T., Donghai, Z., Melinda, W., Nancy, J.L., Sherri, W., & Joseph, A.H. (1995). The influence of aging on muscle strength and muscle fiber characteristics with special reference to eccentric strength. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences, 50*(6), B399–B406. PubMed

Klentrou, P., Cieslak, T., MacNeil, M., Vintinner, A., & Plyley, M. (2002). Effect of moderate exercise on salivary immunoglobulin A and infection risk in humans. *European Journal of Applied Physiology, 87,* 153–158. PubMed doi:10.1007/s00421-002-0609-1

Laurent, S., Pierre, B., Roland, A., Isabelle, G., Brigitte, L., Louis, G., . . . Athanase, B. (2001). Aortic stiffness is an independent predictor of all-cause and cardiovascular mortality in hypertensive patients. *Hypertension, 37*(5), 1236–1241. PubMed doi:10.1161/01.HYP.37.5.1236

Lowery, E.M., Brubaker, A.L., Kuhlmann, E.,& Kovacs, E.J. (2013). The aging lung. *Clinical Interventions in Aging, 8,* 1489–1496. PubMed

MacKinnon, L.T., Chick, T.W., Van, A.A., & Tomasi, T.B. (1987). The effect of exercise on secretory and natural immunity. *Advances in Experimental Medicine and Biology, 216,* 869–876. PubMed doi:10.1007/978-1-4684-5344-7_102

MacKinnon, L.T., & Jenkins, D.G. (1993). Decreased salivary immunoglobulins after intense interval exercise before and after training. *Medicine and Science in Sports and Exercise, 25,* 678–683. PubMed doi:10.1249/00005768-199306000-00005

Miletic, I.D., Schiffman, S.S., Miletic, V.D., & Sattely-Miller, E.A. (1996). Salivary IgA secretion rate in young and elderly persons. *Physiology & Behavior, 60,* 243–248. PubMed doi:10.1016/0031-9384(95)02161-2

Neves S.C., Lima R.M., Simões H.G., Marques M.C., Reis V.M., Oliveira R.J. (2009). Resistance exercise sessions do not provoke acute immunosuppression in older women. *Journal of Strength and Conditioning Research, 23*(1), 259-265. doi:10.1519/JSC.0b013e31818767b9

Newman, A.B., Varant, K., Marjolein, V., Eleanor, M.S., Bret, H.G., Stephen, B.K., . . . Tamara, B.H. (2006). Strength, but not muscle mass, is associated with mortality in the health, aging and body composition study cohort. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences, 61*(1), 72–77. PubMed doi:10.1093/gerona/61.1.72

Nieman, D.C., Henson, D.A., Gusewitch, G., Warren, B.J., Dotson, R.C., Butterworth, D.E., & Nehlsen-Cannarella, S.L. (1993). Physical activity and immune function in elderly women. *Medicine and Science in Sports and Exercise, 25,* 823–831. PubMed doi:10.1249/00005768-199307000-00011

Pistilli, E.E., Nieman, D.C., Henson, D.A., Kaminsky, D.E., Utter, A.C., Vinci, D.M., . . . Nehlsen-Cannarella, S.L. (2002). Influence of age on immune changes in runners after a marathon. *Journal of Aging and Physical Activity, 10,* 432–442.

Robergs, A., & Langwehr, R. (2002). The surprising history of the "HRmax=220-age" Equation. *Journal of Exercise Physiology Online, 5*(2), 1–10.

Sakamoto, Y., Ueki, S., Shimanuki, H., Kasai, T., Takato, J., Ozaki, H., . . . Haga, H. (2005). Effects of low-intensity physical exercise on acute changes in resting saliva secretory IgA level in the elderly. *Geriatrics & Gerontology International, 5*(3), 202–206. doi:10.1111/j.1447-0594.2005.00297.x

Sébastien B. A., Marie-Eve F., Marie-Eve R., Mylène A. L., & Antony D. K. (2012).

Shindo, M., Kumagai, S., & Tanaka, H. (1987). Physical work capacity and effect of endurance training in visually handicapped boys and young male adults. *European Journal of Applied Physiology and Occupational Physiology, 56,* 501–507. PubMed doi:10.1007/BF00635361

Sloan, C.A., Engels, H.J., Fahlman, M.M., Yarandi, H.E., & Davis, J.E. (2013). Effects of Exercise on S-IgA and URS in Postmenopausal Women. *International Journal of Sports Medicine, 34,* 81–86. PubMed

Statistics Korea. (2011). *Estimated future population.* Daejeon, Korea.

Sutton-Tyrell, K., Samer, S.N., Robert, M.B., Akshmi, V., Varant, K., Eleanor, M.S., . . . Newman, A.B.é (2005). Elevated aortic pulse wave velocity, a marker of arterial stiffness, predicts cardiovascular events in well functioning older adults. *Circulation, 111*(25), 3384–3390. PubMed doi:10.1161/CIRCULATIONAHA.104.483628

Tharp, G.D., & Barnes, M.W. (1990). Reduction of saliva immunoglobulin levels by swim training. *European Journal of Applied Physiology and Occupational Physiology, 60*(1), 61–64. PubMed doi:10.1007/BF00572187

Tomasi, T.B., Trudeau, F.B., Czerwinski, D., & Erredge, S. (1982). Immune parameters in athletes before and after strenuous exercise. *Journal of Clinical Immunology, 2,* 173–178. PubMed doi:10.1007/BF00915219

UN. (2012). *World population prospects: The 2012 revision statistics Korea (2011), Estimated future population: 2010-2060.* Lake Success, NY: United Nations.