太极拳训练对老年人静态平衡能力的影响：基于不同训练量

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摘要：目的：静态平衡是指身体在相对静止的状态下，通过调整重心来保持一个姿势或稳定状态的能力。老年人静态平衡能力的研究一直受到广泛关注。平衡是保持身体重心在支撑平面之上的能力。身体重心随着姿势的变化和身体的移动而变化。当人体静止不动时，人体在自身的平衡点周围处于不断摇晃的状态，这种摇晃是主观意识无法控制的。在生理学上，这种现象被称为生理姿势晃动。目前静态平衡能力的测量方法主要是由受试者站在一个固定的生物力学平台上或平板上的高灵敏度的力传感器可以用来记录受试者的身体状况，并经过一系列软件的分析计算出人体静态平衡的评价参数。静态平衡的评价参数包括睁眼和闭眼情况下测量时重心的位置、重心移动路径的面积或区域的面积、重心移动路径的总长度和重心的比值等参数。人体在静止或缓慢移动状态下的 CoP (Center of pressure, CoP)可近似等于人体的重心。因此，本研究采用 CoP 相关参数，可作为评价患者平衡能力的指标。以前的一些研究已经报道过太极拳对老年人平衡能力的影响。然而，对于老年人来说，如何设置训练量来更好地促进老年人静态平衡能力的提高，仍然是一个有待解决的问题。因此，本研究旨在通过设置三种不同的太极拳训练量，探讨太极拳训练对老年人静态平衡能力影响的内在机制。**方法：**30 名 65 岁以上的志愿者自愿参加了这项研究。所有受试者在实验前 3 个月内均经过严格的体检，确保所选受试者身体健康，无下肢肌肉及关节损伤。此外，通过在知情信上签字，确保他们的身体和精神能够经受住考验。所有受试者都可以在任何时候退出研究。实验前受试者明确了解实验过程、实验要求以及实验过程中可能出现的不适。正式实验前，所有受试者的静态平衡能力均采用力平台(AMTI, Watertown, USA，采样频率为 1000hz)测量。受试者首先需要在跑步机上热身 10 分钟。热身结束后，受试者有 5 分钟时间充分熟悉实验环境和实验仪器，然后采集受试者优势腿的静态平衡能力。在实验人员的指导下，受试者由优势腿支撑单腿站在受力平台上，另一条腿的膝关节弯曲 90 度。受试者被要求睁眼状态下单腿站立在测力台上 30 秒。在数据收集过程中，受试者被要求看正前方的一个固定区域。结合静态平衡测试结果，将被试分为三组(A、B、C 组)，三组之间都无显著性差异。三组受试者被要求每周完成 3 次太极训练，

持续 16 周。A 组每次完成 45 分钟太极拳训练，B 组每次完成 60 分钟太极拳训练，C 组每次完成 90 分钟太极拳训练。在 16 周太极拳训练结束时，再次测量三组的静态平衡能力。在实验干预过程中，有一名专业的武术老师和一名医务人员全程陪同，保证了实验的顺利进行和受试者的安全。静态平衡能力测量时，要求受试者在实验人员的指导下站在力平台上，测量并记录静态平衡能力指标，以评价老年人的静态平衡能力。指标包括：CoP 在前-后(AP)和中-侧(ML)方向上的平均位移速度、CoP 的面积、CoP 在 AP 和 ML 方向上的最大位移。该值越低表示静态平衡良好，该值越高表示静态平衡能力较差。所有实验数据导出到 Excel 中，使用 MATLAB R2019a 软件进行计算。通过编辑程序代码计算 CoP 面积，CoP 在 AP 和 ML 方向上的最大位移，以及 CoP 在 AP 和 ML 方向上的平均位移速度。采用 SPSS 25. 0 软件对三组受试者的静态平衡能力数据进行单因素方差分析。用箱线图判断各组数据的正态分布，用 Shapiro-Wilk 检验判断各组数据是否服从近似正态分布。数据以 Mean±SD 表示，本研究的显著性水平设为 P<0. 05。**结果：**A、B、C 组 CoP 面积分别为 701. 20±307. 13 mm2、434. 71±241. 23 mm2、519. 46±251. 08 mm2。三种训练量对受试者 CoP 面积的影响有统计学差异(P<0. 001)。与 A 组相比，B 组和 C 组的 CoP 面积显著小(P=0. 026)。B 组与 C 组比较差异无统计学意义(P=0. 077)。A、B、C 组 CoP 在 ML 方向上的最大位移分别为 43. 67±4. 02、39. 91±4. 94、31. 08±3. 13。三种训练量对受试者在 ML 方向上 CoP 最大位移的影响有统计学差异(P<0. 001)。与 A、B 组相比，C 组 CoP 在 ML 方向上的最大位移显著小(P=0. 019)。A 组与 B 组比较差异无统计学意义(P=0. 058)。A、B、C 组 CoP 在 AP 方向上的最大位移分别为 24. 10±6. 44、23. 51±3. 30、17. 11±3. 02。三种训练量对受试者在 AP 方向上 CoP 最大位移的影响差异有统计学意义(P<0. 001)。与 A、B 组相比，C 组 CoP 在 Ap 方向上的最大位移显著小(P=0. 341)。A 组与 B 组比较差异无统计学意义(P=0. 082)。A、B、C 组 CoP 在 ML 方向上的平均位移速度分别为 915. 17±338. 90 mm/s、971. 07±294. 66 mm/s、894. 30±210. 13 mm/s。三种训练量对受试者在 ML 方向上 CoP 平均位移速度的影响差异无统计学意义(P=0. 641)。A、B、C 组在 AP 方向上 CoP 的平均位移速度分别为 1021. 35±195. 102 mm/s、997. 06±201. 03 mm/s、890. 17±201. 91 mm/s。三种训练量对受试者 AP 方向上 CoP 平均位移速度的影响差异无统计学意义(P=0. 790)。**结论：**本研究的目的是基于三种不同训练量研究太极拳训练对老年人静平衡能力的影响。通过研究发现，静态 CoP 面积随着训练量的增加逐渐减小，但当达到一定水平后，CoP 面积不再出现显著的减小。这意味着静态平衡能力会随着太极拳训练量的增加而提

高，但训练量达到每次 60 分钟后，静态平衡能力不会随着训练量的增加而提高。当训练量达到每次至少 90 分钟时，CoP 在 AP 和 ML 方向上的最大位移显著降低，这意味着可以通过将训练量增加到每次至少 90 分钟来改善身体重心的摇摆情况。此外，研究显示太极拳训练量的增加对 CoP 的平均位移速度没有影响。因此，结合本研究的结果，建议太极拳训练时间每次不少于 60 分钟，以提高老年人的静态平衡能力。

关键词：静态平衡；老年人；压力中心

Effects of Tai Chi training on static balance ability of elderly people: Based on different training volume

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Abstract: Objective: Static balance refers to the body's ability to maintain a posture or a stable state by adjusting its center of gravity in a relatively static state. The study of static balance ability in the elderly has been widely concerned. Balance is the ability to keep the center of gravity of the body above the supporting base plane. The center of gravity of the body changes as the posture changes and the body moves. When the human body stands still, the body is in a state of constant shaking around its own equilibrium point, and the subjective consciousness cannot control such shaking. In physiology, this phenomenon is called physiological posture shaking. Static balance ability of measurement methods at present is mainly by subjects stand on a stationary platform for biomechanics or tablet on the platform of the high sensitivity of force sensor can be used to record the subjects of the body, and after a series of analysis software to calculate the static balance evaluation parameters of human body balance. The evaluation parameters of static balance include the position of the center of gravity of the subject, the area of the center of gravity moving path or the area of the region, the total length of the center of gravity moving path, and the ratio of the center of gravity parameters when the subject is measured with eyes closed and eyes open, etc. The CoP (Center of pressure, CoP) of the human body in a static or slow moving state can be approximately equal to the center of gravity of the body. Therefore, COP related parameters were adopted in this study, which can be used as an indicator to evaluate patients' balance ability. The effects of tai chi practice on balance in older adults have been reported in several previous studies.

However, for the elderly, how to set the training amount to better promote the improvement of the static balance ability of the elderly is still a problem to be solved. Therefore, the purpose of this study is to investigated the internal mechanism of the influence of Tai Chi training on the static balance ability of the elderly by setting three different training volume of Tai Chi exercises. **Methods:** Thirty people over 65 years of age volunteered to participate in the study. All participants were subjected to strict medical screening to ensure that the selected subjects were in good health and had no lower limb muscle and joint injury within 3 months before the experiment. Besides, make sure they are physically and mentally able to withstand the test by sign the informed letter. And all participants are allowed to withdraw from the study at any time. Before the experiment, the subjects were clearly informed of the experiment process, the experiment requirements and the possible discomfort during the experiment. Before the formal experiment, the static balance ability of all subjects was measured by a force platform (AMTI, Watertown, USA, sampling frequency of 1000 Hz). Subjects first need to warm up in the running playground for 10 minutes. Immediately after the warm up, the subjects have 5 minutes to get fully familiar with the experimental environment and experimental instruments, and then collect the static balance ability of the dominant leg of the subjects. Under the guidance of the experiment personnel, the subject stands on the force platform with one leg supported by the dominant leg, and the knee joint of the other leg is bent 90 degrees. The subjects were asked to stand on one leg on a load bench for 30 seconds. During the data collection, the subjects were asked to look at a fixed area directly ahead. Combined with the results of the static balance test, the participants were divided into three groups (group A, B and C) with no significant difference. Participants in all three groups were asked to finish the Tai Chi Training 3 times a week continue 16 weeks. The group A was asked to finish 45 minute Tai Chi Training in each times, the group B and C was asked to finish 60 and 90 minute of Tai Chi Training in each times, respectively. At the end of the 16 weeks of tai chi training, the static balance ability of all three groups was measured again. In the process of experimental intervention, a professional martial arts teacher and a medical staff accompanied the whole process to ensure the smooth progress of the experiment and the safety of the subjects. In the measured of static balance ability, the subjects was asked to stands on the force platform under the guidance of experiment personnel, the index of static balance ability was measured and record to evaluate the static balance ability of the elderly. And the index was including: the average displacement velocity of CoP in the Antero-Posterior (AP) and Medium-Lateral (ML) axis, the area of the CoP, the maximum displacement of COP in AP and ML axis. If the value is low, it means that the static balance is good, and if the value is high, it means that the static balance is poor. All the experimental data were exported to Excel and calculated by MATLAB R2019a software. Calculate the CoP area, the maximum displacement of COP in the AP and ML axis, as well as the average displacement velocity of CoP in the AP and ML axis by editing the program code. The static balance ability data of the three groups of subjects were analyzed by one-way ANOVA using SPSS 25. 0 software. The boxplot was used to determine whether the data of each group were normal, and Shapiro-Wilk test was used to determine whether the data of each group obeyed an approximate normal distribution. Data were expressed in the form of Mean±SD, and the significance level of this study was set as P<0. 05. **Results:** The CoP area of group A, B and C were 701. 20±307. 13 mm^2, 434. 71±241. 23 mm^2 and 519. 46±251. 08 mm^2, respectively. There were a statistically significant differences in the effect of A, B and C training amount on the CoP area of the subjects (P<0. 001). Compared with the group A, the CoP area of group B and C was significant small (P=0. 026). And there are no significant difference between group B and C (P=0. 077). The maximum displacement of COP in the ML axis of group A, B and C were 43. 67±4. 02, 39. 91±4. 94 and 31. 08±3. 13, respectively. There were a statistically significant differences in the effect of A, B and C training amount on the maximum displacement of COP in the ML axis of the subjects (P<0. 001). Compared with the group A and B, the maximum displacement of COP in the ML axis of group C was significant small (P=0. 019). And there are no significant difference between group A and B (P=0. 058). The maximum displacement of COP in the AP axis of group A, B and C were 24. 10±6. 44, 23. 51±3. 30 and 17. 11±3. 02, respectively. There were a statistically significant differences in the effect of A, B and C training amount on the maximum displacement of COP in the AP axis of the subjects (P<0. 001). Compared with the group A and B, the maximum displacement of COP in the Ap axis of group C was significant small (P=0. 341). And there are no significant difference between group A and B (P=0. 082). The average displacement velocity of CoP in the ML axis of group A, B and C were 915. 17±338. 90 mm/s, 971. 07±294. 66 mm/s and 894. 30±210. 13 mm/s. There was no

statistically significant differences in the effect of A, B and C training amount on the average displacement velocity of CoP in the ML axis of the subjects (P=0. 641). The average displacement velocity of CoP in the AP axis of group A, B and C were 1021. 35±195. 102 mm/s, 997. 06±201. 03 mm/s and 890. 17±201. 91 mm/s. There was no statistically significant differences in the effect of A, B and C training amount on the average displacement velocity of CoP in the AP axis of the subjects (P=0. 790). **Conclusion:** The purpose of this study is to investigated the effect of Tai Chi training on the static balance ability of the elderly based on three different training volume of Tai Chi exercises. Through the study, we found that the static CoP area decreased gradually with the increase of training volume, but when it reached a certain level, the CoP area no longer showed a significant decrease. This means that the static balance ability will improve with the increase of the volume of Tai Chi training, however, after reaching 60 minutes each time, the static balance ability will not improve with the increase of the training volume. And for the maximum displacement of COP in AP and ML axis, when the training volume reaches 90 minutes each times, the maximum displacement of CoP in AP and ML axis was significantly lower, which means that the training volume should be increased to at least 90 minutes each times to reduced the swing of body. In addition, the increase of training volume of Tai Chi has no effect on the mean displacement velocity of CoP. Therefore, combination with the results of this study, it is recommended to set the amount of Tai Chi training at no less than 60 minutes each time for improve the static balance ability of the elderly.

Key words: Static balance, Elderly people, Center of pressure