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Original Research

Three-Dimensional Kinematic Analysis of the Lower Extremity in *Ruesi Dat Ton* Postures Performed by Healthy Volunteers

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Abstract

This study was conducted to investigate the three-dimensional (3D) joint angles and muscle activities of the lower extremities when performing the *Ruesi Dat Ton*: a form of traditional Thai medicine involving stretching and strengthening postures. Thirty healthy volunteers were recruited in order to let them perform five *Ruesi Dat Ton* postures, namely *Tha Kae Khao Kae Kha, Tha Kae Lom Nai Ook Nai Eo, Tha Kae Klon Pattakhat, Tha Kae Siat Ook, and Tha Kae Lom Pat-Khat Kae Lom Nai Eo*, by a random sequence of postures. The 3D joint angles and muscle activities during the performance of the *Ruesi Dat Ton* were analyzed at the 3D-motion analysis laboratory. Descriptive statistics were used for the analysis. All the *Ruesi Dat Ton* postures were in the normal range of motion of the back, hips, knees, and ankles. However, when compared to the joint angle values from the 3D motion analysis, a higher joint angle was found in the hip rotation of *Tha Kae Khao Kae Kha* (27.99±16.72 degrees), *Tha Kae Lom Nai Ook Nai Eo* (25.99±14.76 degrees), and *Tha Kae Klon Pattakhat* (20.99±12.59 degrees), knee flexion of *Tha Kae Siat Ook* (140.05±8.98 degrees), and trunk flexion of *Tha Kae Lom Pat-Khat Kae Lom Nai Eo* (52.10±14.83 degrees). All the postures produced more than 1% maximum voluntary isometric contraction of the muscle (MVIC). The muscle activities of *Tha Kae Siat Ook* were the most contracted, whereas *Tha Kae Lom Pat-Khat Kae Lom Nai Eo* were the least. Moreover, the study found that the rectus femoris muscle was the most active muscle in all postures. In conclusion, this research can help to select the most appropriate *Ruesi Dat Ton* posture to maximize the benefits for practitioners and to ensure safety while performing the postures.

Keywords: *Ruesi Dat Ton;* Hermit doing body contortion exercise; Biomechanics; Lower extremity; Human health

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final pose for a while (about five to ten seconds), and repeating each posture for three to five times [2]. The postures are similar to Yoga postures or Indian hermit postures, but omitting the penance element and leaving only the stretching element as a form of therapeutic exercise [3]. Nonetheless, when practitioners practice the *Ruesi Dat Ton* postures, they have to focus on body movement and breathing, similar to Yoga exercises [4-5].

Nowadays, the *Ruesi Dat Ton* postures are used in various ways, for examples, an exercise to improve and maintain health, or combining with Thai traditional massage to be a specific exercise integrated with the treatment. The numerous benefits of the *Ruesi Dat Ton* have been reported including 1) to increase the flexibility and range of motion [6], 2) to improve anaerobic performance [7], 3) to improve quality of life [8-9], 4) to relieve muscle pain [2,10], and 5) to decrease thoracic curvature [11].

Given its many benefits, the Thai government has been keen to promote the integration of Thai traditional medicine into the national healthcare system through the National Health Act (A.D. 2007) [12] and as a part of the various national strategies (A.D. 2007–2021) [13-15]. In addition, many institutions are interested in the *Ruesi Dat Ton* exercises. The exercises have been widely interpreted from the original poetry along with the paintings of the *Ruesi Dat Ton* procedures to develop the simple descriptions of the performance. However, these various interpretations had led to variations in the *Ruesi Dat Ton* methods that can confuse practitioners, and cause a failure to do them effectively, and even expose to a risk of musculoskeletal injuries in case of poor practice. Moreover, the modified *Ruesi Dat Ton* procedures have now become more famous than the traditional ones. Thus, understanding the right movement patterns and muscle activity is essential to explain the traditional *Ruesi Dat Ton* posture characteristics. Currently, studies involving the biomechanics investigation of the *Ruesi Dat Ton* need to be improved. Our previous study investigated the upper extremities' three-dimensional (3D) joint angles and muscle activities in the *Ruesi Dat Ton* postures [16]. The data showed that most postures were within a normal range of motion and had more than 1% maximum voluntary isometric contraction of the muscle (MVIC). Therefore, this study aimed to comprehensively investigate the 3D joint angles and muscle activities of the lower extremities when performing the *Ruesi Dat Ton* postures.

Materials and Methods

Study design

This descriptive study was conducted at the Faculty of Medicine Siriraj Hospital, Bangkok, Thailand. All the volunteers were received a clear explanation of the experiment protocol, risks, and benefits of the study. The informed consents were obtained before the data had been collected. The study protocol was reviewed and approved by the Siriraj Institutional Review Board, Thailand [COA Si 513/2016] and registered in the Thai Clinical Trials Registry (TCTR20221219002).

Subjects and sample size calculation

The healthy volunteers aged between 18 to 32 years old were recruited in the study. The inclusion criteria were a male's waistline of not more than 90 cm and a female's waistline of not more than 80 cm. The exclusion criteria were applied to if pregnancy, musculoskeletal diseases or neurological diseases, or allergic to alcohol or adhesive tape.

The sample size calculation was based on the primary objective, which was similar to the previous study involving the 3D motion analysis of a range of motions of the back in non-lower back-pain volunteers [17], and was determined by using the following aspects: two-tailed test, 95% confidence interval, a standard deviation of 10.30, and acceptable error of 4.3. A total of samples required for this study were thus calculated as 30 volunteers.

The participants' enrollment was also compatible with the eligibility criteria using the convenience sampling method.

Ruesi Dat Ton exercises

The five-selected postures were *Tha Kae Khao Kae Kha* (denoted as T1 posture in the tables and in the later discussion), *Tha Kae Lom Nai Ook Nai Eo* (T2), *Tha Kae Klon Pattakhat* (T3), *Tha Kae Siat Ook* (T4), and *Tha Kae Lom Pat-Khat Kae Lom Nai Eo* (T5) (Figure 1). The procedures were taken from *Kaiborihan Baep Ruesi Dat Ton*, Volumes 1 and 2 [2,18].

Study flow

The volunteers who passed the selection criteria and were included in the study were trained how to perform the *Ruesi Dat Ton* exercises via video media and guided closely by Thai traditional medical practitioners in 120 minutes of training. After completing the training, the volunteers were evaluated by three experienced and expert Thai traditional medical practitioners for how they performed the *Ruesi Dat Ton* postures. Next, the volunteers changed their clothes into skin-tight apparel and stayed barefoot. The volunteer's skin hairs were shaved and the skin was cleaned with alcohol pads to reduce the noise signals in the electromyography (EMG) measurements. Afterward, the surface EMG sensors (Trigno wireless system, Delsys Inc., Boston, MA, USA) were placed on the erector spinae, quadriceps femoris, hamstring, tibialis anterior, gastrocnemius medialis, and gastrocnemius

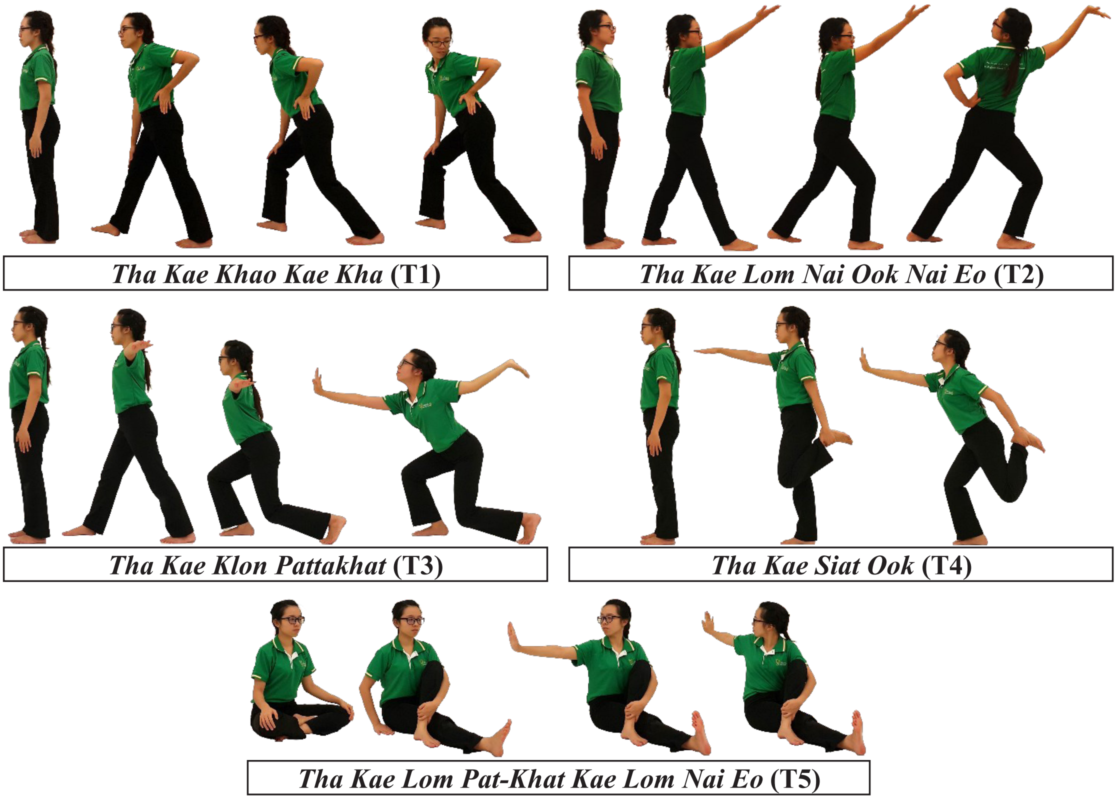

Figure 1. The five *Ruesi Dat Ton* postures; consists of *Tha Kae Khao Kae* Kha (T1), *Tha Kae Lom Nai Ook Nai Eo* (T2), *Tha Kae Klon Pattakhat* (T3), *Tha Kae Siat Ook* (T4) [18], and *Tha Kae Lom Pat-Khat Kae Lom Nai Eo* (T5) [2] which performed in right direction.

lateralis muscles in order to record the muscle activity. The signal rate was set at 1,000 Hz. The maximum voluntary isometric contraction of the muscle (MVIC) was collected by stimulating the static muscle strength [19]. Then, the reflective markers were placed on the participant's anatomical landmarks following the Plug-in-Gait marker set placement [20]. Five *Ruesi Dat Ton* postures were performed for three times on both sides, with a five-minute resting period between each posture. The sequence of the postures was selected by a randomized sampling except for the *Tha Kae Lom Pat-Khat Kae Lom Nai Eo* (sitting posture). Kinematic data were collected by the eight-camera Raptor-E series system (Motion Analysis Corporation, Santa Rosa, CA, USA) at a sampling rate of 100 Hz.

Data processing
The movement pattern was labeled following the Plug-in-Gait maker set. Kinematic and EMG data were analyzed with Visual3D software version 5.0 (C-motion, Germantown, MD, USA).

Data analysis
The participants' demographic data, range of motion of the hip, knees, and ankles, and muscle activities of each posture were analyzed by using descriptive statistics; by mean and standard deviations using the software systems Statistical Package for Social Science (SPSS) version 18 for Windows and Microsoft Office Excel 365.

Results

Participants
This cohort study comprised 15 healthy males and 15 healthy females aged 26.00 ± 3.06 years old, with a body weight of 57.40 ± 9.60 kg, height of 165.80 ± 8.53 cm, and BMI of 20.79 ± 2.41 kg/m2 (normal weight). There was no dropout after all.

Lower extremity joint movement
This study investigated the joint angle in the static pose of the *Ruesi Dat Ton*. For the right direction, with the ankle movement at the X-axis (Table 1), the highest dorsiflexion angle on both sides was found in T3. T1–T4 on both sides showed dorsiflexion of more than 15 degrees, whereas the minimal movement of the right ankle was found in T5 posture. During T5 posture, plantarflexion of the left ankle was at 18 degrees. The ankle movements of T1–T5 at the Y-axis

(Table 2) were negligible. Most postures showed an inversion of less than 15 degrees. Only the left ankle of T3 was in the form of eversion, but less than 5 degrees. At the Z-axis (Table 3), the ankle movements in all postures were in the form of external rotation with not more than 50 degrees, except for the left ankle of T3 which was in the form of internal rotation.

The knee movements at the X-axis (Table 1) were in the form of knee flexion, at which the highest flexion was occurred in T4 (left side), followed by T5 (left side) and T3, whereas the other postures were less than 50 degrees. Only the right knee of T5 posture was found in the form of knee extension. At the Y-axis (Table 2), the knee adduction and abduction were small, i.e., not more than 15 degrees. At the Z-axis (Table 3), the knee movement in all the postures was observed in the form of internal rotation, but not more than 50 degrees, except for the left knee of T3, which was in the form of external rotation.

For the hip movement at the X-axis (Table 1), all the postures were in the form of hip flexion, at which the left hip of T5 posture showed the highest movement, and the right hip in all the postures gave more than 30 degrees of movement, whereas the others showed small degrees of movement. At the Y-axis (Table 2), the most movement of the hip abduction was found in T1, followed by T2 and T3; while T4 and T5 were in hip adduction and not more than 15 degrees. At the Z-axis (Table 3), the right hip movement was in the form of internal rotation, but not more than 30 degrees.

For the trunk movement at the X-axis (Table 1), T1–T4 postures involved trunk extensions; T2 and T4 postures showed the highest actions. In contrast, T5 posture was in the form of trunk flexion. At the Y-axis (Table 2), the trunk lateral flexion was small, and not more than 15 degrees. At the Z-axis (Table 3), T1–T3 were in the form of a right rotation of greater than 15 degrees, whereas T4 posture involved a smaller right rotation. In contrast, T5 posture was in the form of a left rotation.

On the left direction, the ankles, knees, hips, and trunk movement showed the same pattern, but on the opposite side of the leg.

Muscle activities in Ruesi Dat Ton

The back and lower extremity muscle activities during the *Ruesi Dat Ton* are shown in Table 4. The highest biceps femoris activity in the range of 55.65–78.32% MVIC was found in both legs of T3, and the right leg of T4; while the other postures were in the range of 9.51–33.75% MVIC. Erector spinae muscle activity in the range of 12.59–42.07% MVIC was found in almost all the postures, except for T5 which was in the range of 6.14–8.69% MVIC. For the right gastrocnemius lateralis, T1–T4 showed the muscle activity in the range of 35.24–63.89% MVIC; while the others were in the range of 8.75–21.90% MVIC. For the gastrocnemius medialis, the greatest muscle activity at 24.54% MVIC was found on the right side of T4; while the

Table 1. Means and standard deviations (SD) of joint angles at sagittal plane (X-axis) in five *Ruesi Dat Ton* postures

X-axis	Joint angles (degrees, mean ± SD)						
	Ankles		Knees		Hips		Trunk
	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	
T1_rt	15.70 ± 7.93	23.57 ± 11.00	39.33 ± 9.45	17.51 ± 20.20	43.21 ± 13.35	18.27 ± 12.53	-2.80 ± 12.41
T1_lt	24.20 ± 10.53	14.78 ± 7.48	18.50 ± 20.42	41.51 ± 8.56	18.00 ± 15.43	48.50 ± 15.65	-4.60 ± 11.13
T2_rt	23.61 ± 5.82	23.19 ± 11.85	46.12 ± 8.94	30.56 ± 22.57	35.33 ± 11.95	9.71 ± 14.28	-13.89 ± 10.09
T2_lt	22.71 ± 10.13	22.95 ± 6.58	26.24 ± 22.33	46.48 ± 9.67	8.44 ± 13.80	37.96 ± 11.02	-16.34 ± 9.18
T3_rt	26.06 ± 5.87	30.43 ± 7.92	63.58 ± 10.08	67.47 ± 15.53	51.07 ± 10.94	17.34 ± 8.88	-4.86 ± 12.02
T3_lt	33.06 ± 8.50	23.50 ± 6.65	61.73 ± 12.58	61.23 ± 8.11	16.05 ± 11.93	51.60 ± 9.94	-7.79 ± 9.05
T4_rt	24.14 ± 5.61	17.33 ± 9.46	36.29 ± 10.05	135.40 ± 8.75	54.65 ± 8.60	0.55 ± 8.97	-13.80 ± 15.39
T4_lt	19.09 ± 11.12	23.50 ± 6.14	140.05 ± 8.98	36.32 ± 9.02	5.10 ± 8.76	51.55 ± 8.82	-12.76 ± 15.94
T5_rt	0.46 ± 12.29	-18.06 ± 9.19	-5.49 ± 5.19	97.26 ± 8.57	38.77 ± 11.22	85.10 ± 13.02	51.79 ± 14.49
T5_lt	-15.20 ± 9.09	2.85 ± 10.54	98.95 ± 7.84	-6.10 ± 5.82	82.43 ± 13.57	37.64 ± 10.61	52.10 ± 14.83

T1: *Tha Kae Khao Kae Kha*; T2: *Tha Kae Lom Nai Ook Nai Eo*; T3: *Tha Kae Klon Pattakhat*; T4: *Tha Kae Siat Ook*; T5: *Tha Kae Lom Pat-Khat Kae Lom Nai Eo*; _rt: performed in right direction; _lt: performed in left direction; Rt: right side; Lt: left side; (+) value: dorsiflexion, knee flexion, hip flexion, trunk flexion; (-) value: plantarflexion, knee extension, hip extension, trunk extension.

Table 2. Means and standard deviations (SD) of joint angles at frontal plane (Y-axis) in five *Ruesi Dat Ton* postures

Y-axis	Joint angles (degrees, mean ± SD)						
	Ankles		Knees		Hips		Trunk
	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	
T1_rt	7.86 ± 6.63	9.21 ± 9.32	16.54 ± 10.78	-3.14 ± 4.07	-42.86 ± 8.75	10.40 ± 7.18	-1.13 ± 8.64
T1_lt	10.97 ± 10.91	3.63 ± 7.06	-3.89 ± 5.08	13.20 ± 6.16	10.59 ± 6.76	-39.63 ± 10.77	-0.02 ± 8.77
T2_rt	4.97 ± 7.92	12.07 ± 10.78	2.00 ± 12.31	-5.97 ± 5.18	-21.92 ± 13.26	-0.28 ± 8.13	4.65 ± 7.71
T2_lt	14.73 ± 9.21	0.69 ± 7.16	-10.19 ± 8.41	5.09 ± 6.36	-0.63 ± 5.71	-18.80 ± 12.89	-2.41 ± 6.19
T3_rt	0.50 ± 8.33	-2.75 ± 12.28	-5.31 ± 13.69	4.53 ± 7.22	-14.00 ± 9.88	0.85 ± 6.47	8.49 ± 5.78
T3_lt	6.80 ± 8.59	-2.55 ± 8.37	-14.02 ± 11.73	2.02 ± 7.42	-0.14 ± 5.50	-7.77 ± 10.02	-7.86 ± 5.31
T4_rt	3.12 ± 8.01	7.81 ± 11.92	-2.52 ± 6.93	6.09 ± 5.59	0.65 ± 8.48	-8.50 ± 6.21	2.09 ± 6.19
T4_lt	13.49 ± 12.28	-0.77 ± 8.11	-5.63 ± 17.73	1.83 ± 5.15	-10.12 ± 6.57	2.64 ± 10.17	-1.74 ± 7.25
T5_rt	14.42 ± 10.88	12.65 ± 9.42	-0.38 ± 3.17	13.68 ± 7.53	11.48 ± 4.83	10.01 ± 5.08	-6.99 ± 3.98
T5_lt	15.40 ± 7.12	11.13 ± 10.66	17.05 ± 16.35	-2.62 ± 3.11	4.05 ± 5.38	13.83 ± 4.59	6.62 ± 4.93

T1: *Tha Kae Khao Kae Kha*; T2: *Tha Kae Lom Nai Ook Nai Eo*; T3: *Tha Kae Klon Pattakhat*; T4: *Tha Kae Siat Ook*; T5: *Tha Kae Lom Pat-Khat Kae Lom Nai Eo*; _rt: performed in right direction; _lt: performed in left direction; Rt: right side; Lt: left side; (+) value: inversion, knee adduction, hip adduction, right lateral flexion of trunk; (-) value: eversion, knee abduction, hip abduction, left lateral flexion of trunk.

Table 3. Means and standard deviations (SD) of joint angles at transverse plane (Z-axis) in five *Ruesi Dat Ton* postures

Z-axis	Joint angles (degrees, mean ± SD)						
	Ankles		Knees		Hips		Trunk
	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	
T1_rt	-36.64 ± 12.55	-18.92 ± 11.84	19.87 ± 19.11	15.76 ± 10.85	-27.99 ± 16.72	14.68 ± 8.67	24.64 ± 7.42
T1_lt	-19.47 ± 16.13	-44.48 ± 11.19	23.03 ± 20.73	24.92 ± 12.86	1.24 ± 10.29	-26.56 ± 12.62	-21.97 ± 6.44
T2_rt	-39.57 ± 12.21	-17.09 ± 12.58	36.94 ± 16.50	18.02 ± 12.16	-25.99 ± 14.76	14.73 ± 10.23	21.11 ± 6.63
T2_lt	-16.48 ± 13.66	-42.49 ± 11.19	25.75 ± 17.81	34.90 ± 11.39	-0.40 ± 10.81	-18.78 ± 12.02	-18.70 ± 5.84
T3_rt	-43.53 ± 11.24	29.90 ± 12.88	44.51 ± 16.01	-30.02 ± 15.34	-20.99 ± 12.59	-11.14 ± 8.63	18.91 ± 5.73
T3_lt	-26.86 ± 11.01	-47.47 ± 12.24	27.86 ± 16.16	42.11 ± 13.35	-2.43 ± 11.75	-10.02 ± 7.76	-15.43 ± 4.05
T4_rt	-38.65 ± 11.38	-33.57 ± 19.33	38.59 ± 15.65	28.31 ± 20.88	-16.77 ± 13.07	5.86 ± 8.58	6.91 ± 5.05
T4_lt	-27.19 ± 21.45	-42.10 ± 10.78	10.59 ± 32.10	33.90 ± 9.49	-4.77 ± 20.37	-5.26 ±7.15	-5.44 ± 5.13
T5_rt	-12.88 ± 13.32	-35.19 ± 21.35	18.58 ± 17.29	19.07 ± 22.50	-4.69 ± 12.66	-14.76 ± 8.58	-32.62 ± 11.77
T5_lt	-44.24 ± 20.15	-17.64 ± 12.21	34.09 ± 19.51	10.32 ± 13.58	-11.34 ± 16.03	6.00 ± 8.02	32.18 ± 9.86

T1: *Tha Kae Khao Kae Kha*; T2: *Tha Kae Lom Nai Ook Nai Eo*; T3: *Tha Kae Klon Pattakhat*; T4: *Tha Kae Siat Ook*; T5: *Tha Kae Lom Pat-Khat Kae Lom Nai Eo*; _rt: performed in right direction; _lt: performed in left direction; Rt: right side; Lt: left side; (+) value: ankle internal rotation, knee internal rotation, hip internal rotation, right rotation of trunk; (-) value: ankle external rotation, knee external rotation, hip external rotation, left rotation of trunk.

others were in the range of 6.38–17.06% MVIC. The results showed that T3 and T4 had the greatest right rectus femoris muscle activity in the range of 88.22–88.47% MVIC, followed by the right leg of T1 and T2, and the left leg of T3, which had the similar muscle activities in the range of 52.30–58.77% MVIC. Over and above, the similar rectus femoris muscle activity in the range of 44.65–46.35% MVIC was found on the left leg of both T1 and T2, whereas the muscle activity in the range of 18.26–36.42% MVIC in T5. For the tibialis anterior, the muscle activity in the range of 4.93–29.81% MVIC was found in all the postures.

Table 4. Back and lower extremities muscle activities in *Ruesi Dat Ton* postures

Posture	Muscle activity (%MVIC)											
	Biceps femoris		Erector spinae		Gastrocnemius lateralis		Gastrocnemius medialis		Rectus femoris		Tibialis anterior	
	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.
T1_rt	19.18	33.75	16.76	20.91	35.24	20.64	15.05	16.43	52.30	44.65	9.24	21.45
T1_lt	25.99	42.99	24.02	18.23	20.81	32.72	14.87	15.96	33.94	74.20	27.05	11.17
T2_rt	27.94	26.81	12.59	32.83	39.15	21.90	15.82	14.53	56.28	46.35	21.73	11.82
T2_lt	18.95	51.27	35.55	15.60	25.03	38.12	13.82	17.43	30.92	66.37	14.99	24.24
T3_rt	55.65	78.32	16.29	29.20	47.34	12.67	17.06	8.20	88.47	58.77	28.43	26.51
T3_lt	29.58	75.52	29.30	20.21	18.58	40.49	9.86	16.50	52.95	84.00	28.46	27.19
T4_rt	73.22	26.15	42.07	24.57	63.89	11.36	24.54	7.94	88.22	32.09	29.81	29.73
T4_lt	12.83	92.82	23.45	39.39	8.54	57.82	9.53	24.72	40.81	77.50	30.95	29.20
T5_rt	17.56	9.51	8.69	6.14	8.75	10.57	6.38	6.88	36.42	18.26	17.00	4.93
T5_lt	8.44	45.27	7.54	6.50	11.17	8.88	5.79	5.61	60.04	38.14	3.34	18.03

T1: *Tha Kae Khao Kae Kha*; T2: *Tha Kae Lom Nai Ook Nai Eo*; T3: *Tha Kae Klon Pattakhat*; T4: *Tha Kae Siat Ook*; T5: *Tha Kae Lom Pat-Khat Kae Lom Nai Eo*; _rt: performed in right direction; _lt: performed in left direction; Rt: right side; Lt: left side; %MVIC: muscle activity percentage.

Table 5. Overall results for the most joint movement and muscle activities in *Ruesi Dat Ton*

<table>
<tr><th></th><th></th><th></th><th>Ankles</th><th>Knees</th><th>Hips</th><th>Trunk</th></tr>
<tr><td colspan="2" rowspan="3">Joint angle (degrees)</td><td>X-axis</td><td>T3</td><td>T4</td><td>T5</td><td>T5</td></tr>
<tr><td>Y-axis</td><td>T2</td><td>T1</td><td>T1</td><td>T3</td></tr>
<tr><td>Z-axis</td><td>T3</td><td>T3</td><td>T1</td><td>T5</td></tr>
<tr><td colspan="7">Muscle activities (%MVIC)</td></tr>
<tr><td></td><td>Biceps femoris</td><td>Erector spinae</td><td>Gastrocnemius lateralis</td><td>Gastrocnemius medialis</td><td>Rectus femoris</td><td>Tibialis anterior</td></tr>
<tr><td>T1</td><td rowspan="5">leading: 17.56–73.22
trailing: 9.51–78.32</td><td>16.76–20.91</td><td rowspan="2">20.64–39.15</td><td rowspan="2">15.05–16.43</td><td rowspan="5">leading: 36.42–88.47
trailing: 18.26–58.77</td><td rowspan="2">9.24–21.73</td></tr>
<tr><td>T2</td><td>12.59–32.83</td></tr>
<tr><td>T3</td><td>16.29–29.20</td><td>12.67–47.34</td><td>8.20–17.06</td><td rowspan="2">26.51–29.81</td></tr>
<tr><td>T4</td><td>24.57–42.07</td><td>11.36–63.89</td><td>7.94–24.54</td></tr>
<tr><td>T5</td><td>6.14–8.69</td><td>8.75–10.57</td><td>6.38–6.88</td><td>4.93–17.00</td></tr>
</table>

T1: *Tha Kae Khao Kae Kha*; T2: *Tha Kae Lom Nai Ook Nai Eo*; T3: *Tha Kae Klon Pattakhat*; T4: *Tha Kae Siat Ook*; T5: *Tha Kae Lom Pat-Khat Kae Lom Nai Eo*; _rt: performed in right direction

Discussion

This is the first study of the biomechanics in the *Ruesi Dat Ton* postures related to the back and legs. The objective was to investigate the joint angles and muscle activities when the *Ruesi Dat Ton* postures were performed. The joint movements were observed by the same method used in a previous study [21]. Most joint angles fell into the reference joint range of motion in the young, healthy group (aged 20–29 years old). However, we found that some postures have the greater range of motion as compared to the reference. For example, we found that a higher hip external rotation in T1–T3 postures on the right direction and T1 posture on the left direction. A higher knee flexion of the trailing leg was found in T4 posture whilst a greater knee extension and trunk flexion in T5. The discrepancy may be due to the measurement methods. The range of motion in this study was obtained from 3D-motion analysis system during performing a complex movement of the *Ruesi Dat Ton* postures. Albeit the sitting postures may not be appropriate for older adults or people with knee or hip pain, it could be concluded that the *Ruesi Dat Ton* postures are safe to practice, according to our result on the trunk range of motion which is within the normal limit [22-23].

Understanding the muscle activity pattern of performing the *Ruesi Dat Ton* postures is significant for selecting or recommending these exercises to the practitioners. This study investigated the muscle activities of the back and lower extremities. We found that the highest rectus femoris activities across T1–T4 posture, which may aid quadriceps strengthening. Therefore, these postures may be recommended to a patient after rectus femoris tendonitis or tendinopathy healed, or patients with knee osteoarthritis. Additionally, practicing these postures can prevent acute muscle injury from muscle fatigue [24]. For example, fatigued muscles are able to absorb less energy which can lead to change in neuromuscular coordination patterns [25]. Improper or repetitive motion will eventually lead to injury. Moreover, T3 and T4 postures are helpful for dynamic knee joint stabilization by strengthening biceps femoris muscle, which is beneficial for people who suffer from lower back pain or recurrent hamstring strain. Furthermore, a high erector spinae and gastrocnemius lateralis muscles activities were found in T4 posture which is a one-legged standing posture. Considering the function of these muscles, it is suggested that integration of T4 posture into a balance exercise program might help to improve balance and prevent falls, which would be especially useful for older adults and athletes. Other muscles that were less active in any postures were not mentioned. In addition, the result showed a high movement of the back in T5 posture, on the other hand less erector spinal muscle activity. This finding recommended T5 posture to be practiced to relieve stiffness in the lower back, lumbar strain, and lumbar spine osteoarthritis pain.

There are a number of limitations in this study to be noted, including that the reflective markers easily disappeared when performing T4 and T5 postures. To maintain the visibility of the reflective markers, the volunteers had to adjust some positions, which could have biased the joint angle data. Moreover, sweating was problematic as it could cause an easier displacement of the surface EMG devices. When performing T5 posture, the volunteers were sitting on the devices, which could have distorted the muscle activities, which in turn leading to some error in the reported data.

Therefore, further study should seek to optimize the placement of the reflective markers and to study different types of participants to determine the joint movement and muscle function characteristics of each group. In addition, further investigation should be conducted for full-body motion analysis, because each posture also involves a large movement of the upper part of the body.

Conclusion

This study shows the characteristics of the joint angles and muscle activities in the back and lower extremities in people performing the *Ruesi Dat Ton* postures, which can act as a guideline for choosing the appropriate postures for practitioners to ensure the maximum efficacy and safety. In addition, this research provides the strong evidence to support the benefits of Thai traditional medicine.

Conflict of Interests

None.

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