# MECHANICAL EFFICIENCY ACCORDING TO THE DYNAMIC WALKING APPROACH PRINCIPLES

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## ABSTRACT

The purpose of this study was to provide mechanical information about healthy adult walking mechanical efficiency from the perspective of a dynamic approach. The focus was to analayze step-to-step transition (STST) mechanical cost of transport (MCOT) at high intensity walking gait. A twenty-five healthy adult males participated in the study from Sport Science and Physical Education department at Hashemite University in Jordan. Ariel performance analysis system (APAS) to find the preferred transition speed (PTS), and the BTS SMART-DX were used to gather data for and for Analysis System to explore kinematical characteristics. The results showed stance phase duration of 0.479 ± 0.03 s for trailing leg (T.leg) and 0.447 ± 0.02 s for leading leg (L.leg), where the double stance phase (DSt) is 0.110 ± 0.03 s for T.leg and 0.100 ± 0.03 s for the L.leg with STST-MCOT 9.6 ± 0.06 J and mechanical efficiency percentage of 9.6 %.

It is highly recommended to consider locomotor mechanical efficiency assessment as essential of life style and to maintain stride-to-stride fluctuations, which may correlate to loss of stability. In addition, to further study the effect of race walkers and its related effects of STST adaptation.

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**الملخص :**

كان الغرض من هذه الدراسة هو توفير معلومات ميكانيكية حول الكفاءة الميكانيكية للمشي للبالغين الأصحاء من منظور نهج ديناميكي. كان التركيز على تحليل التكلفة الميكانيكية للنقل خطوة إلى خطوة (STST) في مشية الخطو عالية الشدة. شارك في الدراسة خمسة وعشرون من الذكور البالغين الأصحاء من قسم علوم الرياضة والتربية البدنية في الجامعة الهاشمية في الأردن. تم استخدام نظام تحليل (APAS)للعثور على سرعة الانتقال المفضلة (PTS) ، وتم استخدام

BTS SMART–DXلجمع البيانات من أجل نظام التحليل لاستكشاف الخصائص الحركية. أظهرت النتائج أن مدة طور الوقوف 0.479 ± 0.03 ثانية للساق الخلفية (T.leg) و 0.447 ± 0.02 ثانية للساق الرئيسية (L.leg) ، حيث تكون مرحلة الوقوف المزدوج 0.110 ± (DSt) 0.03ثانية للساق الخلفية .(T.leg) و 0.100 ± 0.03 ثانية لـ L.leg مع STST–MCOT لـ J 0.06 ± 9.6ونسبة كفاءة ميكانيكية 9.6٪. يوصى بشدة بالنظر في تقييم الكفاءة الميكانيكية الحركية كأمر أساسي لنمط الحياة وللحفاظ على تباين خطوة بخطوة ، والتي قد ترتبط بفقدان الاستقرار والثبات. بالإضافة إلى ذلك ، لمزيد من الدراسة لتأثير رياضة سباق المشي والآثار المرتبطة بتكيف STST.

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## MECHANICAL EFFICIENCY ACCORDING TO THE DYNAMIC WALKING APPROACH PRINCIPLES

**Introduction:**

Walking and running were the first means of locomotion known by human beings. Studying the Gait Cycle (GC) phase's features and its mechanical efficiency, in order to provide practical solutions which, lead to healthy, efficient locomotion is crucial.

The public health of any society is conditioned by the individual physical health. To attain optimal health requirements, it is necessary to study locomotion in order to present scientific data. These valued data should be used in health management programs related to locomotor efficient and proficient performance (Harold, Bill Kohl, Tinker Murray, 2011). However, the engagement of life plays a role in ignorance of locomotor health and its dynamic functionality. In turn, this affects individual occupational health due to the instability of functional performance. Thus, in this image, a locomotion health standard related to dynamic functionality, and proficient performance becomes a priority on stage. Studies agree in dividing the walking gait into two phases, Stance phase (St) and Swing phase (Sw), with a ratio of 60% for St and 40% for Sw (Perry J, 1992, Kilani, 2013). Twenty percent of GC is distinguished by a special sign in which it characterizes the walking gait. It is the Double Stance phase (DSt); when it disappears, the transition occurs to change the gait mode from walking to running upon a specific velocity termed the preferred transition speed (PTS) (Doucende, Rissetto, Mourot & Cassirame, 2017) . However, high intensity walking gait has become an interesting field of research since it has variables that may contribute to creating standard measures of locomotion at high speed. This can be taken as an indicator of gait proficiency.

Biomechanical motion analysis is a very useful tool because its importance comes from considerable data that can be used to provide useful quality standards and precise locomotor occupational therapy protocols. Indeed, studies have revealed rich data which increase the interest in studying the walking gait for different reasons and research objectives, as in sport medicine and other applied sport science related fields (Dusko Ilic, Vladimir Ilic, Vladimir Mrdakovic, Nenad Filipovic. 2012). Also to understand the transition from one step to another, and to study mechanical characteristics which sometimes can be link to the physiological characteristics of energy.

Actually, the purpose of any scientific research is to attain facts based on extracted results that can be used in other research or be applied in other fields such as applied sports science, the fitness industry and health care. In spite of, the variability of studies' objectives and manifold studies which introduce valuable scientific illustration, we focused on locomotor mechanical efficiency with the perspective of dynamic walking approach principles and its mechanical cost of transport (MCOT) during step-to-step transition (STST) at a high intensity walking gait.

**Importance and implementations of the study:**

In the light of stature deformity caused by repeated wrong locomotion patterns, and its effect on locomotor mechanical efficiency and MCOT, which in turn causes harm to occupational health. This study may present considerable data that can be used to provide useful quality standards and precise locomotor occupational therapy protocols.

From the available scientific literature, we observed that some studies express different opinions of the way of evaluating the gait MCOT and its efficiency. Nevertheless, this is considered available data, the matter which aroused interest in this study.

Furthermore, since prevention is better than cure, the importance of this study lies in giving data which may participate, in addition to previous studies that aimed to assess locomotor efficiency.

Motion analysis in sport domain has an essential role in offering services utilized by exercise designers. In addition, to the lack of local related studies and the need for essential data, we believe that such a study and research in this domain will be very important.

Purpose of the study:

The main purpose of this study is to provide mechanical information about subject locomotor mechanical efficiency from the perspective of a dynamic walking approach by studying the mechanical characteristic of STST and MCOT at a high intensity walking gait.

**Methods:**

Subject: Twenty-five subjects are recruited from students of the Sports Science and Physical Education College, Hashemite University, Jordan.

**Table (1), depicts the 25 subjects' characteristics.**

| Characteristics | (Mean ± SD) |
|---|---|
| Age (year) | 21 ± 2.1 |
| Height (cm) | 179 ± 2.5 |
| Mass (kg) | 84 ± 2.0 |
| Asis breadth (cm) | 15 ± 0.4 |
| Right pelvis depth (cm) | 11.5 ± 0.2 |
| Left pelvis depth (cm) | 11.5 ± 0.17 |
| Right leg length (cm) | 88 ± 0.8 |
| Left leg length (cm) | 87.7 ± 0.6 |
| Right knee diameter (cm) | 9.5 ± 0.2 |
| Left knee diameter (cm) | 9.5 ± 0.1 |
| Right malleolus width (cm) | 7 ± 0.07 |
| Left malleolus (cm) | 7 ± 0.05 |

**Research tools:**

In order to perform this study, the following tools were used:

- Treadmill
- Sticking tape (5cm width)
- Video camera (3 no.)
- Infrared Cameras (6 no.)
- Retro Reflective Markers:
  Retro-reflective markers are all 25mm spheres covered in 3M retro-reflective tape. The wand markers are attached to 50mm stalks, which in turn are attached to flexible rubber bases.
- Force Platform – Kisler. (2 no.).
- Pedestrian Bridge (7.5m).
- Stop watch.
- Registration forms.
- APASS analysis system.
- BTS SMART-DX analysis system.
- Video frame trimming software.

- Three dimensions reference (60 cm each axis).
- Calibration wand (stick).

**Procedures:**

- Obtaining approval to participate (confirmation of consent):
  After an explanation to the subjects of the procedures of the study, and its objectives, the approval of participants has been taken.
- Lab mobilization and set up procedure:
  Subjects arrived at the laboratory on two occasions, so prior to both experiments the researcher insured safety.

**Experiment (1) protocol:**

Experiment goal is to find the PTS at treadmill.

Lab mobilization and calibration:

1. Insuring the readiness of treadmill and its working condition.
2. The treadmill's belt has been divided into equivalent spaces by sticking the tape (1m each) in order to calibrate speed.
3. The three video cameras were capturing during the functioning of the treadmill at different speeds for calibration.

**Subject preparation**

The participants were barefoot and instructed to practice several trials for the purpose of warming up.

**Experiment procedure**

The performance speed was increased every minute in order to find the subject's preferred transition speed (the gait mode changing from walking into running for three minutes). Speeds were 1.8 m/s – 1.85 m/s - 1.90 m/s – 1.95 m/s – 2.00 m/s – 2.10m/s – 2.20 m/s -2.30 m/s -2.40 m/s - 2.50 m/s – 2.60 m/s.

After finding the preferred transition speed, another six minutes of practice were allowed for subjects to be familiar with the study's walking gait speed.

**Experiment (2) protocol:**

**Lab mobilization and set up:**

**1. Infrared cameras distribution procedure:**

Cameras were positioned accurately so that they post the best possible view of the marker during performance. The six BTS motion capture system cameras were set up around the lab walkway. Figure 1 shows the distribution of cameras in the laboratory at Hashemite University – Jordan.

The cameras are adjusted until the volume of walkway for each camera is as large as possible.

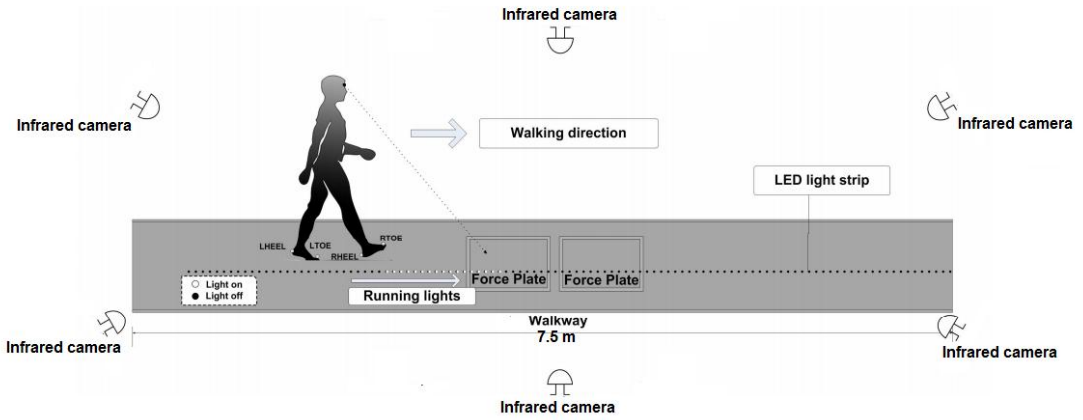



**Figure 1: The distribution of infrared cameras at the laboratory**

## 2. Speed control procedure:

To control over ground walking speed. An LED speed control system was used (Figure 1). "The system includes a custom-made 10 meters digital LED strip and a digital microcontroller. By controlling the duration time of the power supply to each LED unit, a visible running lights signal can provide a visual cue for speed control" (Liang Huang, Jie Zhuang and Yanxin Zhang, 2013)

## 3. Calibration procedure:

The calibration procedure is done in two steps. First a static calibration is performed to determine the global X, Y, Z axes of the walkway (Figure 2), then a dynamic calibration is performed to calibrate the walkway volume.

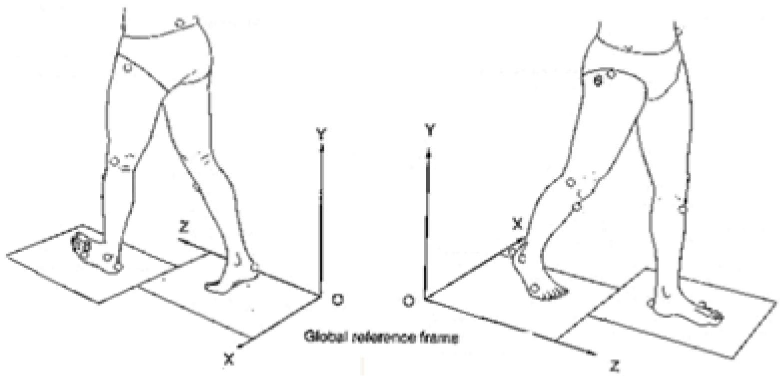



**Figure 2: The global X, Y, Z axis of the walkway**

The dynamic calibration is performed by waving a wand which has two 50 mm markers attached 500mm apart. The wand is moved throughout the walkway in an attempt to calibrate the entire measurement volume. Once calibration is completed, the BTS smart analyzer software reports the calibration residual errors for each camera.

To ensure accurate measurement by the cameras, the calibration procedure is repeated before each subject trial until a residual error of less than 1.5 mm is recorded for each camera.

**4. Subject mobilization:**

Once the anthropometric data are recorded, retro-reflective markers are attached to the subject according to the marker positions of the Davis and Helen Hayes marker set protocols.

The markers are attached using clear double-sided tape, while the wand marker bases are attached with strapping tape. All markers are attached directly to the skin.

With the markers firmly in place, the subject stands on the force platform facing in the global Z direction. A static trial is then recorded and checked to ensure that all markers are visible.

**5. Data Capture Procedure:**

Marker trajectory data are captured with the BTS smart analyzer capture system at a capture frequency of 120 Hz. The ground reaction force data are captured with a frequency of 120 Hz. The force plate and camera data are synchronized by the BTS SMART-DX analysis system. The system reconstructs the markers in three dimensions from the individual camera data.

**6. Data processing Procedure:**

In order to obtain, interpret, and present information about the kinematical characteristics at high intensity walking gait, BTS SMART-DX analysis system procedure and protocol was used.

In order to present, interpret ,and obtain information about the mechanical cost of step to step transition at high intensity walking gait with the perspective of dynamic walking approach principles the researcher performed the data processing procedure of the simple model of inverted pendulum with step to step transition (Kuo AD, et al. 2005).

The mathematical details of STST are as follows:
From Newton's law:

$$\dot{\vec{v}}_{com} = \frac{1}{M}\left(\vec{F}_{lead} + \vec{F}_{trail}\right) + \vec{g} \qquad [1]$$

Where $\vec{F}_{\text{lead}}$ and $\vec{F}_{\text{trail}}$ are the ground reaction forces from L.leg and T.leg. M is body mass, and $\vec{g}$ is the gravitational acceleration.
Integration to yield the change in velocity:

$$
\begin{aligned}
\vec{v}^{+}_{\text{com}} - \vec{v}^{-}_{\text{com}} &= \frac{1}{M}\int_{t-}^{t+} \vec{F}_{\text{lead}}\,dt + \frac{1}{M}\int_{t-}^{t+} \vec{F}_{\text{trail}}\,dt + \int_{t-}^{t+} \vec{g}\,dt \\
&= \hat{F}_{\text{lead}} + \hat{F}_{\text{trail}} \int_{t-}^{t+} \vec{g}\,dt
\end{aligned} \quad [2]
$$

Where $\hat{F}_{\text{lead}}$ and $\hat{F}_{\text{trail}}$ are each leg's integrated and body mass–normalized contribution to redirecting the COM.
In this simple model, the Pythagorean Theorem may be applied to yield the T.leg and L.leg work:

$$
\begin{aligned}
W_{\text{trail}} &= \frac{1}{2} M (v_{\text{com}} \tan\alpha)^2 \\
W_{\text{lead}} &= -\frac{1}{2} M (v_{\text{com}} \tan\alpha)^2
\end{aligned} \quad [3]
$$

Where $v_{\text{com}}$ the (scalar) COM speed, and $\alpha$ is the half angle between the legs.
The predicted work from each leg is approximated by:

$$
\begin{aligned}
W_{\text{trail}} &\propto M (v_{\text{com}} \tan\alpha)^2 \\
W_{\text{lead}} &\propto M (v_{\text{com}} \tan\alpha)^2 .
\end{aligned} \quad [4]
$$

The robustness of equation 4 to model features and parameters makes it well suited to experimental testing.
In order to present, interpret and obtain information about the COM work and quantify the individual limbs' contributions to net COM work $W_{\text{com}}$:

$$
\begin{aligned}
W_{\text{com}} &= \int \vec{F}_{\text{lead}} \cdot \vec{v}_{\text{com}}\,dt + \int \vec{F}_{\text{trail}} \cdot \vec{v}_{\text{com}}\,dt \\
&= \int P_{\text{lead}}\,dt + \int P_{\text{trail}}\,dt \\
&= W_{\text{lead}} + W_{\text{trail}}
\end{aligned} \quad [5]
$$

Where $P_{lead}$ and $P_{trail}$ are the instantaneous power or rate of COM mechanical work, and $W_{lead}$ and $W_{trail}$ are the work per step for each leg
The mechanical cost of transport (positive COM work over a step, divided by body weight and distance traveled)

**Results**:

The main purpose of this study is to provide mechanical information about the subject locomotor mechanical efficiency with the perspective of dynamic walking approach principles, by studying the mechanical characteristic of STST and its MCOT at high intensity walking gait. Thus to attain the study purpose, the study questions have to be answered.

To answer the first question" What are the kinematical characteristics at high intensity walking gait?" We collected the data using BTS SMART-DX analysis system to explore the trajectories of T.leg and L.leg foot, also, the spatial-temporal variables at high intensity walking gait.

The trajectories of T.leg and L.leg explored in graphs (1), (2) & (3).

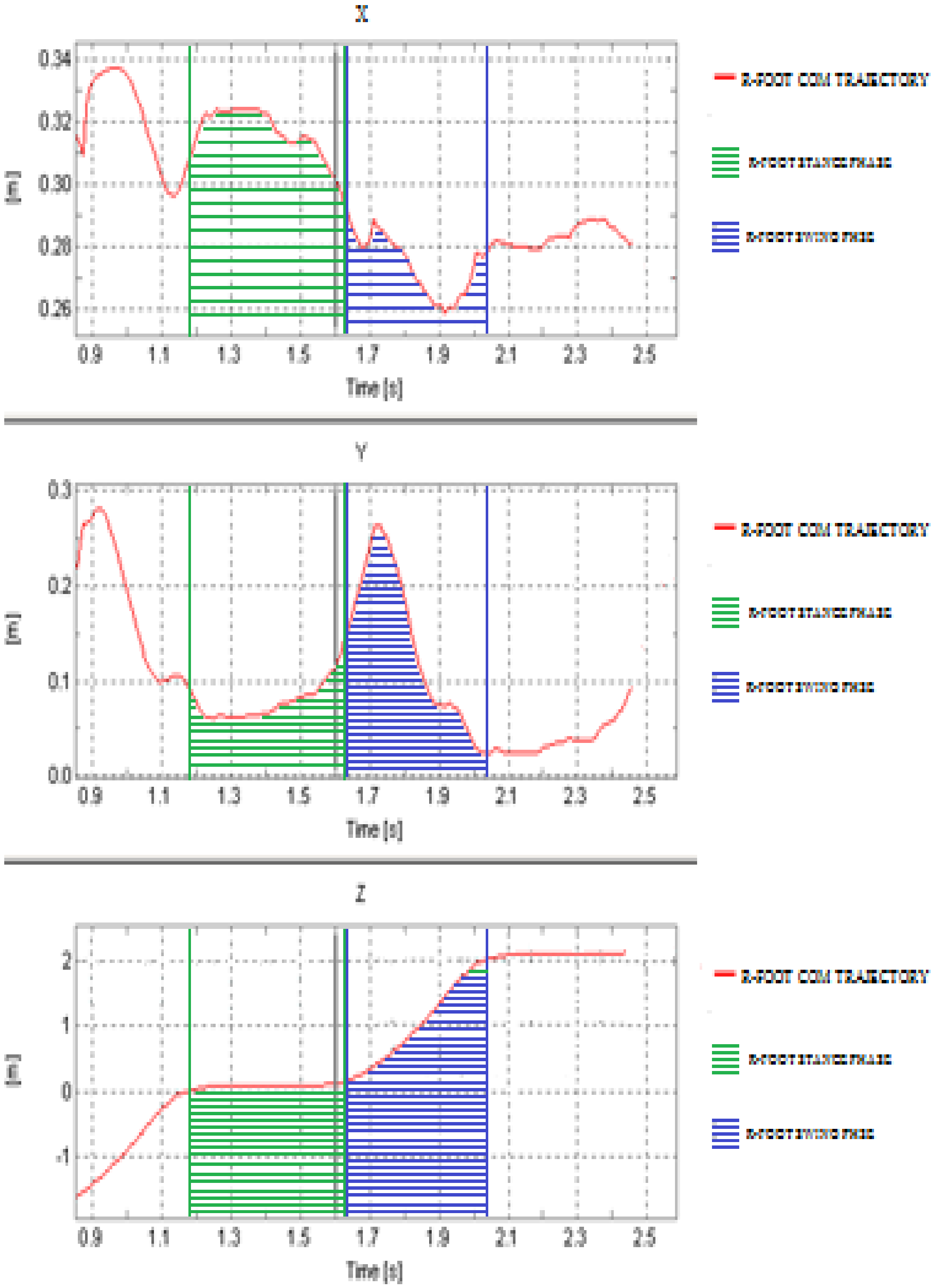



**Figure 1: T. leg foot trajectory at high intensity walking gait cycle**

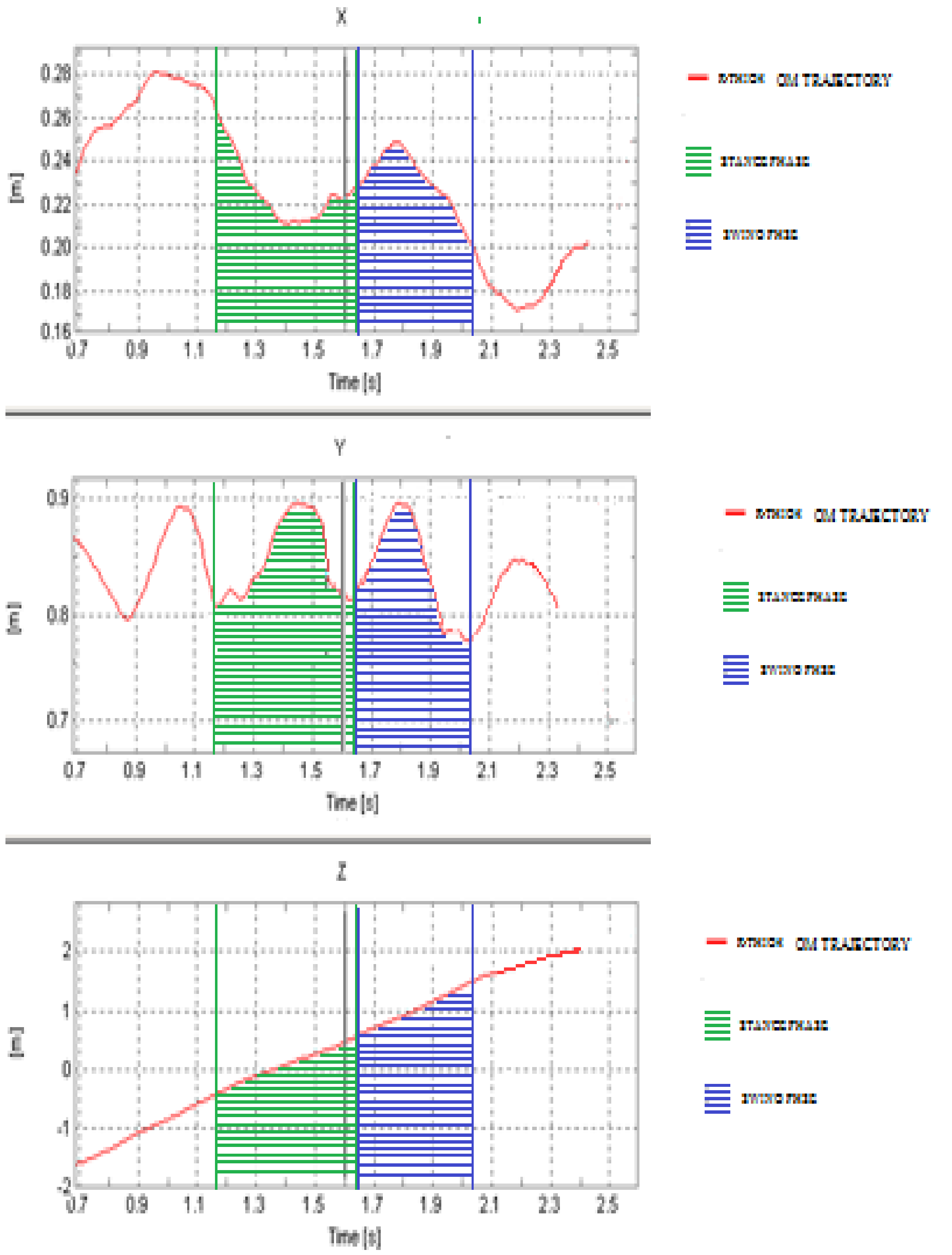



**Figure 2: COM trajectory at high intensity walking gait cycle**

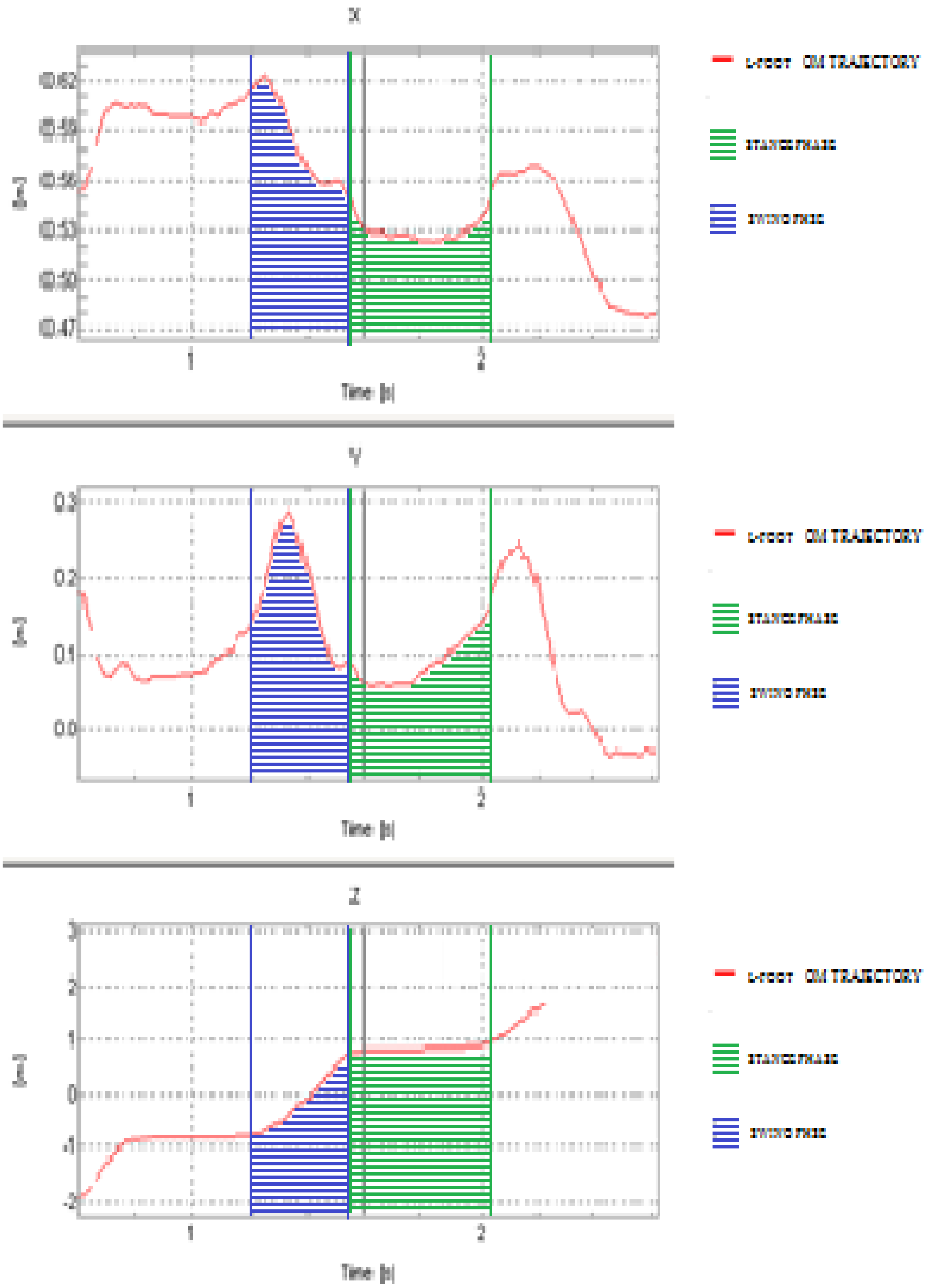


Figure 3: L.leg foot trajectory at high intensity walking gait cycle

For the spatial-temporal variables a descriptive statistic (Mean ± SD) were reported in table (2) and table (3).

**Table 2: Mean values and SD of temporal parameters at high intensity walking gait**

| TEMPORAL PARAMETERS | (Mean ± SD) | |
|---|---|---|
| | T.leg | L.leg |
| STANCE PHASE (S) | 0.479 ± 0.03 | 0.447 ± 0.02 |
| SINGLE STANCE (S) | 0.369 ± 0.03 | 0.347 ± 0.03 |
| DUBLE STANCE (S) | 0.110 ± 0.03 | 0.100 ± 0.03 |
| SWING PHASE (S) | 0.347 ± 0.03 | 0.369 ± 0.03 |
| STRIDE TIME (S) | 0.826 ± 0.03 | 0.794 ± 0.03 |
| PTS (m/s) | 2. 21 ± 0. 27 | |
| CADENCE (step / min ) | 143.71 ± 0.33 | |

**Table 3: Mean values and (SD) of distance parameters at high intensity walking gait**

| DISTANCE PARAMETERS | (Mean ± SD) | |
|---|---|---|
| | T.leg | L.leg |
| STEP LENGTH (m) | 0.96. ± 0.1 | 0.87 ± 0.15 |
| STRIDE LENGTH (m) | 1.94 ±0.16 | 1.84 ±0.2 |
| STEP WIDTH (m) | 0.25 ±0.3 | 0.23 ± 0.2 |
| MEAN VELOCITY (m / s) | 2. 21 ± 0. 27 | |

To answer the second question," How much is the locomotor STST - MCOT?" We had collected the subjects' data using BTS SMART-DX analysis system synchronized with tow Kistlar force platforms system to study the ground reaction forces GRF for T.leg and L.leg during STST in graph (5), (6). GRF at STST Mean values and SD of T.leg and L.leg in (Table 4)

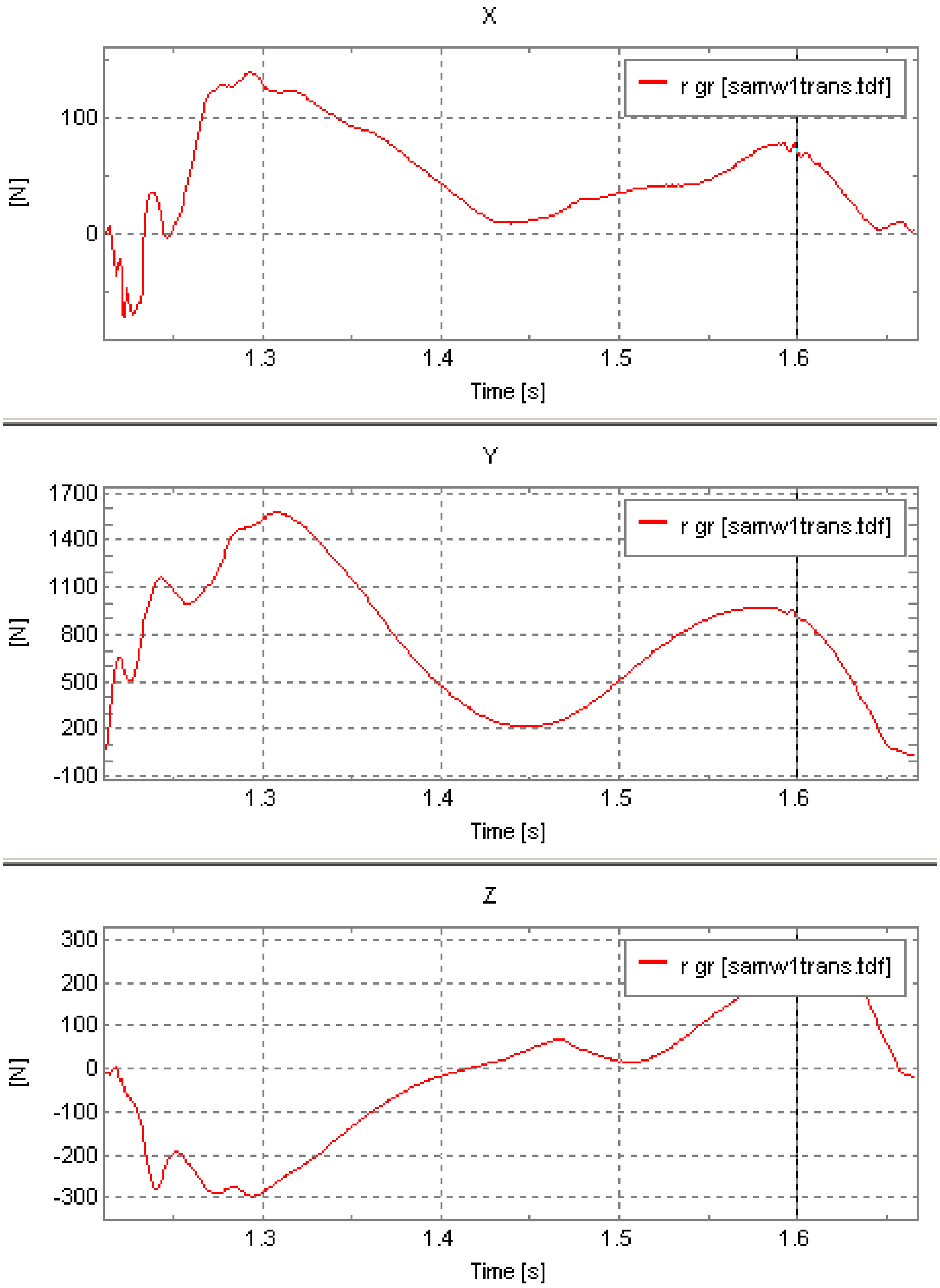
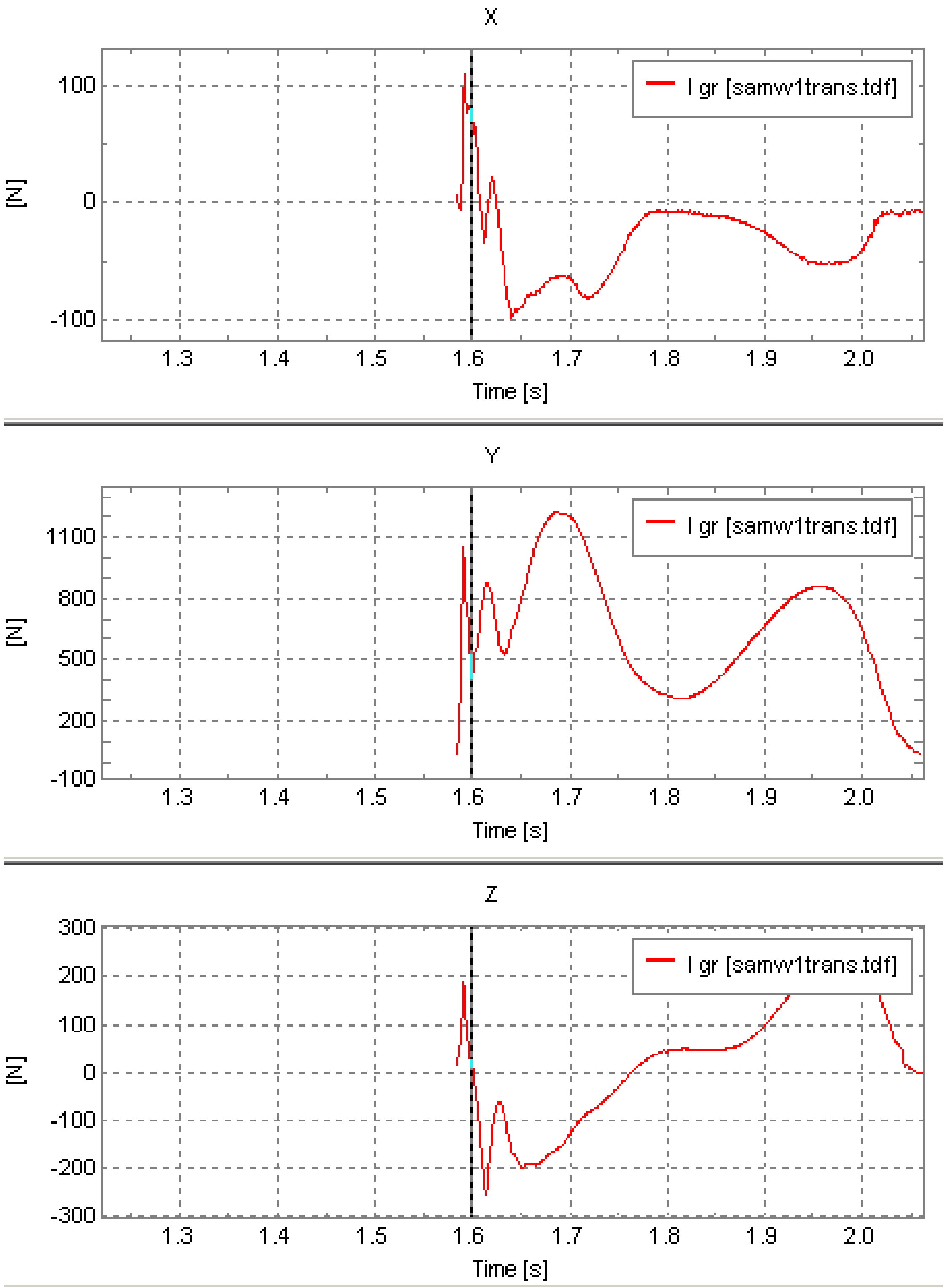



**Figure 4: T.leg GRF at high intensity walking gait cycle**




**Graph 5: L.leg GRF at high intensity walking gait cycle**

**Table 4: Mean values and SD of T.leg and L.leg GRF at STST**

| GROUND REACTION FORCE | Mean ± SD | |
|---|---|---|
| | T.leg | L.leg |
| GRF (N) | 963.00 ± 0.6 | 874.00 ± 0.6 |
| GRF(N.Kg) | 1.146 ± 0.016 | 1.04 ±0.015 |

**Table 5: Mean values and SD of T.leg and L.leg work, COM work and mechanical cost at STST**

| | Mean ± SD | |
|---|---|---|
| | T.leg | L.leg |
| WORK (N/Kg) | 55± 0.45 | -45.4± 0.65 |
| COM. WORK (N/Kg) | 9.6 ± 0.6 | |
| STST mechanical cost (J/Kg/step) | 9.6 ± 0.6 | |

To answer the third question "What is the mechanical efficiency of STST at high intensity speed?"

Considering that the inverted pendulum approach is the energetically optimal approach. In principles, the STST optimal mechanical efficiency occur when T.leg and L.leg perform equal amount of work during double stance phase where the total amount of positive and negative work is minimized, and no work need to be performed during single support. Thus, the researcher calculated the mechanical work dissipation by calculating the instantaneous collision in order to yield the mechanical efficiency. Instantaneous collision and mechanical efficiency values are given in (Table 6).

**Table 6: Mean values and SD of instantaneous collision and mechanical efficiency at STST**

| | Mean ± SD | |
|---|---|---|
| | Optimal | Subject |
| Instantaneous collision | 0.00 | 9.6 ± 0.6 |
| Mechanical efficiency % | 0.096 ± 0.6 | |

**Discussion:**

The main purpose of this study is to provide mechanical information about the subject locomotor mechanical efficiency with the perspective of dynamic walking approach principles, by studying the mechanical characteristic of STST, and MCOT at high intensity walking gait.

Preferred transition speed PTS, commonly occurs at approximately 1.9-2.1m/s some studies have reported slightly higher means near 2.3 m/s, although other studies have reported slightly lower means near 1.9 m/s (Nilsson, Thorstensson, and Halbertsma, 1985; Hreljac, 1995).

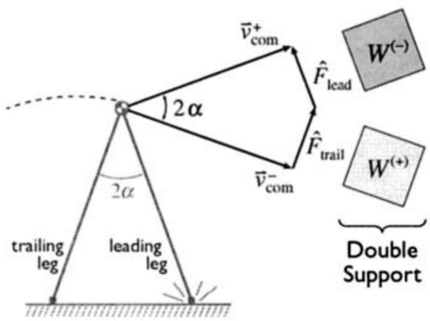
Theoretically it's considered that the maximum attainable speed of an inverted pendulum can be predicted with the dimensionless Froude number (the ratio between centripetal force and gravitation force), therefore, the maximum Froude number is 1.0, where centripetal and gravitational forces are equal. In this study Froude number is 0.56 at subjects PTS, while the literatures demonstrated that humans make the transition from walking to running at a Froude number around 0.5 (Kelso, Buchanan, and Wallace, 1991; Kadar, Schmidh, and Turrey. 1993). In the principles of simple pendulum model, the body's center of mass moves in an arc with a radius equal to leg length L, and the acceleration of the center of mass toward the foot is a = $v^2/L$. As the study subject leg length is 0.88 m, this model predicts a maximum walking speed of about 3.0 m/s, which is much greater than the observed PTS 2.21 ± 0.27 m/s in this study. The PTS exact value may depend on sample characteristics such as body size or athletic training. The literature demonstrates that the contribution of PTS and its mechanical variables changes along with the level and method of training. Furthermore, it's also shown that the transition speed is linked to the subjects' type of training. To conclude, it seems that acquiring locomotion techniques through specific training has consequences for the PTS. (Helene Beaupied, Franck Multon, Paul Delamarche. 2003) However, Biomechanical variables and other factors such as the influence of the human capacity for intentional gait modification and the importance of the physiologic and metabolic demands of the different gaits may also influence the PTS.

The study subjects perform a mean velocity of 2.21 ± 0.27 m/s and 143.71 ± 0.33 step/min cadences while the stride time is 0.826 ± 0.03 and 0.794 ± 0.03 s. with an interval of 0.110 ± 0.03 s and 0.100 ± 0.03 s of DSt for both T.leg and L.leg GC respectively. Moreover, the distance gait parameters in table 2 represents a variation in step length 0.96± 0.1, 0.87 ± 0.15 m and step width 0.25 ±0.3, 0.23 ± 0.2 m.

These stride-to-stride fluctuations may correlate to the loss of stability due to the increased walking speed. In literature it has been shown that it is expected that there will be a loss of stability when walking speed is increased. (Yamasaki M, Sasaki T, Torii M,1991: Hausdorff JM, Purdon PL, Peng CK, Ladin Z, Wei JY, Goldberger AL, 1996; Terrier P, Turner V, Schutz Y, 2005; Jeffrey M Hausdorff, 2005).

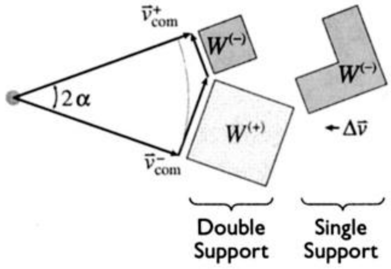
Kimberlee Jordan a, John H. Challis, Karl M. Newell. 2005, have demonstrated a U-shaped relationship between stride length (speed and/or cadence) and measures of gait variability and the coefficient of variation CV of the majority of variables (stride interval, step interval, stride length, step length) decreased with speed. Thus, gait cycle intervals are appearing to be speed dependent. However, physiological factors including cardiovascular changes and musculoskeletal fatigue may also influence the variability of gait and affects gait dynamics include neural control, muscle function and postural control. (Takakusaki K. 2017; Hausdorff JM, Nelson ME, Kaliton D, Layne JE, MacKinnon 2018; Hausdorff JM, Peng CK, Goldberger AL, Stoll AL, 2004; Shung, de Oliveira, & Nadal, 2009). Neuron engineering, motor control and clinical rehabilitation scientists speculate that stride time variability reflects gait timing mechanisms and the pattern generator of gait where the gait cycle becomes more consistent as speed increases, on the other side, variability of support time and step width more closely reflect balance control. Thus, it is likely that there are factors other than speed and general health of the locomotor that affects the average size of GC variations and stride-to-stride fluctuations.

With the perspective of dynamic walking approach, the locomotor optimal mechanical efficiency of STST is illustrated in literatures considering the inverted pendulum approach as the energetically optimal approach (Cavagna et al., 1977; Arthur D. Kuo, J. Maxwell Donelan, and Andy Ruina, 2005). (Graph 6)




Graph 6: Geometric diagram of STST optimal mechanical efficiency where the total amount of positive and negative work performed by both T.leg and L.leg is zero and no work need to be performed during single support.

The STST-MCOT in this study is 9.6 J/Kg/step due to the work resultant performed at COM 13.24 N.m. The T.leg performs positive amount of work 55 N/Kg, while the L.leg performs negative amount of work 45.4N\Kg at STST duration which leads to an energy dissipation of 9.6 J/Kg/step. (Graph 6)




Graph 7: Geometric diagram of the work performed by subject T.leg and L.leg

The subject locomotor mechanical efficiency according to STST-MCOT is 13% due to the magnitude of negative work of L.lge collision which exceeds the T.leg positive work.
Research has illustrated that if the collision exceeds the T.leg work, the next step begins with smaller velocity. To maintain steady walking speed, velocity can be increased by performing additional positive work during single support

**Conclusion:**

This study provides mechanical information about the subject locomotor mechanical efficiency with the perspective of dynamic walking approach principles, by studying the mechanical characteristic of STST, and MCOT at high intensity walking gait. Dynamic walking is a theoretical approach to locomotor which emphasize the use of simple dynamical models in an attempt to understand or promote stability and energy economy. Thus, mechanical work for step-to-step transitions appears to be a major determinant of the metabolic cost of walking. Furthermore, the studies agree that the inverted pendulum approach is energetically optimal among all strategies (srinivasan and ruina, 2006). In this study the locomotor mechanical efficiency 9.6% affected by energy dissipation due to the variation of work applied by the trailing leg and leading leg where the L.leg perform more negative work, theoretically, it is costlier if the legs do not perform equal amounts of work during double support because of additional work needed during single support to maintain a steady walking speed.

High intensity walking speed appear to be a challenge to locomotor gait, it affects performance of gait cycle intervals, furthermore, the evident from literature emphasize that it is expected that there will be a loss of stability when gait increased speed, also, the variability and coefficient of variation of the majority of variables (stride interval, step interval, stride length, step length) decreased with speed.

**Recommendation:**

Measuring mechanical efficiency is potentially useful to assess motor performance, the concept of step-to-step transitions may help guide the design of rehabilitation strategies, rehabilitation devices, and assistive devices aimed at lowering metabolic cost and increasing patient mobility and stability.

The scientific and technological community should start giving a preferential attention to the locomotor dynamic assessment in order to pin point the potential deviation from normal effective pattern of locomotion.

It’s highly recommended to consider locomotor mechanical efficiency assessment as an essential element for life style and to keep maintaining the stride-to-stride fluctuations which may correlate to the loss of stability. Furthermore, gait analysis is necessary to be as part of the routine primary health care visit for people.

It's highly recommended to take into consideration the importance of this domain in further scientific research to have more understanding of the physical fitness level effects on locomotor mechanical efficiency and improving PTS through designing a training programs. A regular interval walking program of 30 min/day is the best single activity for maintaining mobility.

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