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The Effect of Kinesiology Tape During Isotonic Knee Flexion Extension Exercise on Time to Fatigue, Rate, and Quadricep Muscle Oxygenation

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THE EFFECT OF KINESIOLOGY TAPE DURING ISOTONIC KNEE FLEXION EXTENSION EXERCISE ON TIME TO FATIGUE, RATE, AND QUADRICEP MUSCLE OXYGENATION

by

Yu-Wei Wang

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ABSTRACT

THE EFFECT OF KINESIOLOGY TAPE DURING ISOTONIC KNEE FLEXION EXTENSION EXERCISE ON TIME TO FATIGUE, RATE, AND QUADRICEP MUSCLE OXYGENATION

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Under the Supervision of Professor Naira Campbell-Kyureghyan

Some Kinesiology Tape manufacturers claim that Kinesiology Tape (KT) can enhance performance and increase blood flow. Therefore, this study recruited 14 healthy male subjects (college population, 182.9 ± 5.1 cm, 76.52 ± 10.2 kg). to complete an eight-day KT intervention experiment. On Day 1 and Day 2 the subjects did not wear KT. During Days 3 to 6 the subjects wore the KT on their dominant leg (treatment leg) only. Limb dominance was defined by asking the subjects which leg they use to kick a ball. During Days 7 and 8 the subjects did not wear KT. Furthermore, the KT was not worn on the non-dominant leg (control leg) during the study. During testing each subject performed a fatiguing isotonic flexion/extension exercise with a single leg on a Biodex, and switched to the other leg after the first leg exercise was complete. Fatigue was defined by when a subject could no longer perform the exercise.

The time to fatigue (TTF), number of cycles, and rate (number of cycles over TTF) were recorded as performance measures. Muscle oxygenation data including sitting baseline, minimum rSO_2 levels, and time to minimum rSO_2 levels in the trial were assessed to determine the influences of KT on blood flow. The confidence level

in this research was set at 95%. The time series was analyzed to check the root cause of any performance enhancement.

The results suggest that KT did not enhance the performance since the TTF and rate increased most of the days in both the taped and control legs. Furthermore, the time series analyses support the finding that the TTF and rate performance was enhanced by a learning effect. The muscle oxygenation results suggest the Vastus Medialis (VM) minimum rSO_2 were increased by the KT. Even though the Vastus Lateralis (VL) sitting baseline show a statistically significant increase (p=0.045), the Power analysis suggest that the results need more subjects to avoid type I error. In conclusion, the KT type and brand utilized in this research did not support the manufacturers claim regarding enhanced performance. However, the muscle oxygenation results did show a difference when KT was on the treatment leg.

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Chapter 1: Introduction

1.1 Background

Muscle soreness and muscle pain are common side effects after exercising and strenuous work activity. Usually people take pills or use ointments to reduce the pain, which might have some side effect or require dietary restrictions, etc. As an alternative, in the 1970s, Dr. Kenzo Kase developed Kinesiology Tape (KT) which advertises that it can help rehabilitate individuals suffering from muscle pain and soreness. Not only do KT manufacturer's claim to balance the muscles strength during exercise, but also delay fatigue, improve endurance and oxygenation of the muscle, and reduce pain and the likelihood of injury.

In previous studies the KT has been applied to the leg or arm muscles (Gart, 2016), which are the body parts that usually get sore after exercising. Different sports, people and injuries will have different demands. However, KT can also be used on other muscles such as the waist (Gak, 2011). The research also states that KT may be a supplementary treatment method for acute LBP, and could be used in the prevention and treatment of occupational LBP. Another study looked at the neck muscles (González-Iglesias, 2009) which claims that KT significantly improves the pain and cervical range of motion, but may not be clinically meaningful.

In 1980 Dr. Kase established the Kase Chiropractic Institute and the kinesio-taping method that provided correct application guidance to the user. Correct application of the KT is supposed to enhance the efficiency of recovery (Kase, 2003). Dr. Kase, who invented the tape, explained that the fundamental concept of KT is that, after adhesion, it will stretch the skin to promote blood flow and improve

performance, which will function to both protect from injury and enhance rehabilitation following injury.

During the 1990s, after the KT patent expired, many competitor companies started introducing similar tapes. The tape manufacturer's nowadays claim that the tape can not only improve recovery from muscle pain, but also can enhance user's performance, reduce fatigue, improve blood flow to the muscles, and even prevent injury. Numerous athletes have begun using the tape to enhance performance as well. For example, a famous basketball player in the NBA - James Harden - puts on the tape for every game. James Harden's reasoning is that he believes that KT can prevent him from getting injured, and can also maximize his performance through increasing blood flow.

1.2 Previous Research

A Google Scholar search revealed over 20,000 research articles related to KT were published since 1990. Due to the nature of KT claims, most of the research studies were targeting a specific muscle or a group of muscles to which the tape was applied. Further, different parameters of muscle performance (isometric, isokinetic, isotonic) were commonly used in the investigations

Isometric: An exercise where the subject exerts against a fixed object (velocity equals zero), with the position determined by the experiment designer, and exertions must be maintained for at least six seconds. Isometric exercises are used to determine the maximum muscle strength (Perrine, 1969).

Isokinetic: Eccentric/concentric contraction at a constant velocity defined by the experiment designer. The resistance varies throughout the range of motion and the test is used to determine maximum strength (Perrine, 1969).

Isotonic: A dynamic motion flexion/extension exercise with constant resistance and variable velocity. The maximum strength occurs over a short portion of the range of motion determined by the properties of the limb lever system (Iellamo, 1997).

The acute effect of KT application has been widely researched at a number of joints, including the ankle (Simon, 2014; Fayton, 2013; Bicici, 2012; Shields, 2013; Briem, 2011; Wilson, 2015; Halseth, 2004), neck (González-Iglesias, 2009; Saavedra-Hernandez, 2012), legs (Wong, 2012; Fu, 2008; Huang, 2011; Słupik, 2007), back (Gak, 2011), and shoulder (Kaya, 2010; Simsek, 2013; Hsu, 2009). However, only a few published studies have investigated longer-term KT application effects (H.J. Tsai, 2009; A. Ibrahim, 2015; A. Castro-Sánchez, 2012; D. Duracoglu, 2005; S. Bicici, 2012; M. Gramatikova, 2016; M. Thelen, 2008).

Some previous studies have also been conducted with patients to investigate recovery efficiency (Ptak, 2013; Kaya, 2010; Luque-Suarez, 2014; Ibrahim; MacGregor, 2005; Castro-Sánchez, 2012; Duracoglu, 2005; Briem, 2011; Shields, 2013; Jackson, 2016; Simon, 2014; González-Iglesias, 2009). Other studies have been conducted using healthy participants to investigate the effect on performance (Konishi, 2013; Poon, 2015; van Dieen, 2007; Gak, 2011; Tsai, 2009; Huang, 2011; Soylu, 2011; Słupik, 2007; Aktas, 2011; Lee, 2010).

A summary of some of the studies conducted using KT or otherwise having direct relevance to the current study is contained in Table 1. The studies included in this review were chosen based on the claims from Kinesiology Tape to enhance exercise performance and increase muscle oxygenation. Finally, other studies are included that investigated similar topics to the current study: leg exercises, case

control studies, the use of healthy subjects, or duration effects.

A study by Ruggiero et al. (2016) considered a 30 minute KT application to the lumbar spine of 24 low-back pain patients during isometric flexion-extension exercise. While the findings from this study indicate that after the KT was in place for a period of time that there was an enhancement of seated balance compared to a control, whether the results were caused by KT or by a learning effect is unknown because the experimental design did not consider daily data collection. In addition, the findings indicate that KT did not enhance the seated balance control in the short-term since the improvement persisted after the KT was removed, suggesting that the root cause is related to learning effect.

KT has also been studied in the area of low back pain (LBP) since it is a very prevalent worldwide problem and affects 60% to 85% of the population during their lifetime (Burton, 1996). A three-day KT study found that the subjects who have LBP had improved muscle function and a progressive increase in trunk performance after KT application in addition to physical therapy (Gak, 2011).

A recent study investigated KT application for neck pain relief and posture correction. In the neck pain relief study (González-Iglesias, 2009), forty-one patients were chosen, and separated randomly into 2 groups. The experimental group had KT application with tension on the subjects' cervical spine; the placebo group had the same KT application, but it was placed without tension. The cervical range-of-motion was collected immediately after placement of the KT and 24 hours after taping. The results showed that the KT was more effective than the placebo.

In a postural correction study (Luque-Suarez, 2014) 130 participants were included and the two groups of KT application (with and without tension) were split

randomly. At 1 minute, 10 minutes, 60 minutes and 24 hours after taping the FPI score was collected to check on postural changes. The results demonstrated that 24 hours of KT application was not found to be effective for patients with a pathological foot pronation.

Kaya (2010) conducted a study comparing KT application in addition to physical therapy modalities for patients with shoulder impingement syndrome. Significantly better arm and shoulder disability scores were achieved with the KT when compared to therapy alone. The authors also suggest that the KT could be used to cure shoulder impingement syndrome.

KT has also been used to aid in the recovery of proprioception among knee osteoarthritis patients. Sensorimotor training was compared to KT application and the training produced a better outcome (Ibrahim, 2015). The authors conclude that traditional sensorimotor training cannot be replaced by KT application therapy.

A study involving healthy subjects investigated the effect of KT placement on the lumbar portion of the spine and found significant improvements in subject maximal extension peak torque (Knapman, 2016). A competitor of KT claimed that it not only reduces patellofemoral pain (PFP), but also enhanced subjects' isometric strength performance (MacGregor 2005).

Some previous studies collected data from healthy subjects to assess hand (Fu, 2008) and knee joint (Pliner, 2015) performance during isokinetic exercises after KT application. Both studies revealed that a short-term taping didn't exhibit any significant improvements. The findings from another study by Wong (2012) showed no effect on isokinetic test knee torque generation with KT application using a Biodex. However, the time to peak extension torque in that study was significantly

reduced with KT application. The authors did not believe that KT application enhanced performance. However, the authors do not explain whether the finding was due to a “learning” effect or just a “placebo”.

In another study (Poon, 2014), 30 healthy subjects participated using 3 different treatments: true facilitative KT, sham KT, and no KT. A knee isokinetic task was designed to investigate if the KT application on the quadriceps affects the normalized peak torque, normalized total torque, and time to peak torque at different speeds. The KT application was reported to either have a positive effect on the subjects or a “placebo” effect was present.

The possible benefits of KT were also tested for the rectus abdominis muscle during force-velocity parameters of trunk flexors using Biodex equipment (Plak, 2013). A study group (32 people with tape) and a control group (20 people with no tape) were recruited, and each subject performed an isokinetic task with 5 consecutive trunk flexion/extensions at a fixed angular velocity. The study group had KT applied after the first test. No significant difference was found between groups in this short-term isokinetic test.

Ibrahim et al. (2015) designed an 8 week long test to determine the influence of KT and sensorimotor training on the efficiency of osteoarthritis (OA) patients during knee isokinetic exercises, but the study did not record and test consistently over the entire period. The result show that even though both techniques showed significant enhancement in performance, the sensorimotor training provided better improvement in exercise performance, which was collected by Biodex and a visual analogue scale, but the KT application produced greater pain reduction. However, it is possible that patients had recovered by themselves after 8 weeks.

J.H. van Dieen (2009) used a Biodex, EMG, and NIRS to assess when the trunk extensor muscles fatigue during low-level activity, and how muscle activity and muscle oxygenation change in healthy subjects. The results show that NIRS and EMG are not correlated with each other. Although KT application is absent in this research, it nevertheless provides a good reference for discussing fatigue along with muscle oxygenation.

Maximal de-oxygenation of the muscles was examined in a study by Moalla (2006) without KT. 12 healthy children participated, and an isokinetic dynamometer recorded data during subject isometric exercise performance. NIRS and EMG were also used to record the muscle oxygenation and muscle activity. The results suggest that decrease in muscle oxygenation and blood volume is related to isometric exercise.

1.3 Research Gaps and Study Motivation

Based on a review of the published KT research several gaps in knowledge can be identified. Although many KT research studies were designed to test with an exercise task, only a few of the studies were tested with isotonic exercise (Bicici, 2012; Lee, 2011; Pliner, 2015; Cheng, 2005). Bicici (2012) used isotonic exercise on ankle sprains, and Lee (2011) tested the ankle but without KT, Cheng (2005) assessed leg muscle recovery of isotonic power, and the study from Pliner (2015) is the pilot for this research. Most of the published articles (Knapman 2016; Wong 2012; Poon 2014; Vithoulk, 2010; Ptak 2013; Fu, 2012; Aktas, 2011; Lins, 2012) used isometric or isokinetic (Moalla, 2006; MacGregor, 2005; Kaya, 2010; Gramatikova, 2016; Briem, 2011; Fahs, 2015; Castro-Sánchez, 2012; Ruggiero, 2015) exercise to examine muscle strength and torque produced. In this study,

isotonic exercise will be used to assess the performance of knee muscle fatiguing and fill the gap in knowledge.

Experiment duration is another gap. Although several studies used a long duration test (Table 1), very few have recorded the data every day. Some studies have only conducted testing at the beginning and end of the experiment (Tsai, 2009; Ibrahim, 2015), while others have only recorded the data after a period of time (Castro-Sánchez, 2012; Duracoglu, 2005; Bicici, 2012; Gramatikova, 2016; Thelen, 2008; Akbas, 2011). While a small number of papers collect the data throughout the experiment duration (Paoloni, 2011; Saavedra-Hernandez, 2012; Tsai, 2010; Simsek, 2013), none of the studies investigated fatigue or muscle oxygenation.

In particular, only two pilot studies discuss the muscle oxygenation in KT application (Pliner, 2015; Shah, 2017), which is an important topic to investigate due to the manufacturer claims that the muscle oxygenation will be changed by KT, and the increasing of muscle oxygenation can reduce the risk of injury. Regional oxygen saturation (rSO_2) level is the variable that this study measured to present the muscle oxygenation result. In addition, only the pilot study in this research (Pliner, 2015) discusses the duration of flexion/extension exercise and its relationship with time to fatigue (TTF) and rate (frequency).

In this study, an eight-day isotonic knee flexion/extension fatigue experiment in which the data was collected every day was designed. The performance data collected were muscle regional oxygen saturation (rSO_2) levels, time to fatigue (TTF), number of cycles and rate (calculated by number of cycles over TTF). None of the variables have been adequately explored in the past with regards to KT application. The chosen task was knee flexion-extension since the study was a

case-control study design, and the dominant and non-dominant legs have been shown to have similar performance for the task (van der Harst, 2007). Other research also states that the two legs have close performance on different tasks (K. McCurdy, 2005; I. Sannicandro, 2014).

1.4 Specific Aims and Hypotheses

Based on the research gaps identified above, the goals of this case-control research study are threefold:

i. Assess the effectiveness of KT during an isotonic fatiguing knee flexion/extension exercise protocol by measuring the TTF and the number of cycles or rate.
ii. Investigate the effect of KT application over an extended number of days.
iii. Examine the residual effect after removal of the KT application.

The specific aims are:

1. Quantify the effect of acute KT application on TTF of the knee joint during a fatiguing isotonic knee flexion/extension exercise, investigate the effect of the duration of KT application on the TTF, and also examine the residual effect on TTF after KT is removed.

   Hypothesis 1: The acute KT application will delay the TTF in the treatment leg during the fatiguing isotonic knee flexion/extension exercise, the effect will become more prominent as the duration of tape application increases, and additionally have a residual effect to maintain or increase the TTF after KT is removed.

   Hypothesis 1a: The acute KT application will delay the TTF in the

treatment leg.

Hypothesis 1b: The duration of KT application will have a positive effect on the TTF.

Hypothesis 1c: The residual effect will maintain the delay of TTF after removal of KT.

2. Quantify the effect of acute KT application on the rate of knee joint motion during a fatiguing isotonic knee flexion/extension exercise, investigate the effect of the duration of KT application on the rate, and also examine the residual effect on rate after KT is removed.

   Hypothesis 2: The acute KT application will increase the rate in the treatment leg during the fatiguing isotonic knee flexion/extension exercise, the effect will be more prominent with duration of tape application, and the improvements will be maintained or increased after removal of the KT.

   Hypothesis 2a: The acute KT application will increase the rate in the treatment leg.

   Hypothesis 2b: The rate will increase with continued KT application.

   Hypothesis 2c: The residual effect after KT application will exist and increase the rate in the treatment leg.

3. Quantify the sitting baseline of rSO_2 level increase due to acute KT application to the knee joint before the fatiguing isotonic knee flexion/extension exercise, investigate the effects of duration of KT application on sitting baseline rSO_2 level changes, and additionally examine the residual effect on the sitting baseline rSO_2 levels after KT removal.

Hypothesis 3: The acute KT application will increase the sitting baseline of muscle rSO_2 levels in the treatment leg before the fatiguing isotonic knee flexion/extension exercise, the effect will be more prominent with duration of tape application, and additionally will also have a residual effect to maintain or increase the sitting baseline of muscle rSO_2 levels after KT removal.

Hypothesis 3a: The sitting baseline of rSO_2 levels will increase after acute KT application.

Hypothesis 3b: The sitting baseline of rSO_2 levels will increase with duration of KT application.

Hypothesis 3c: The sitting baseline of rSO_2 levels will increase by the residual effect from KT application.

4. Quantify the minimum of rSO_2 level changes due to acute KT application to the knee joint during the fatiguing isotonic knee flexion/extension exercise, investigate the effects of duration of KT application on minimum rSO_2 level changes, and additionally examine the residual effect on the minimum rSO_2 levels after KT removal.

Hypothesis 4: Acute KT application will change the minimum of muscle rSO_2 levels in the treatment leg flexors/extensors during the fatiguing isotonic knee flexion/extension exercise, the effect will be more prominent with duration of tape application, and additionally there will be a residual effect to maintain or change the minimum rSO_2 levels after KT removal.

Hypothesis 4a: The minimum of rSO_2 levels will change after acute KT application.

Hypothesis 4b: The minimum of rSO_2 levels will change due to duration of KT application.

Hypothesis 4c: The residual effect after KT application will exist and change the minimum rSO_2 levels in the treatment leg.

5. Quantify the time to minimum rSO2 level changes due to acute KT application to the knee joint during the fatiguing isotonic knee flexion/extension exercise, investigate the effects of duration of KT application on time to minimum rSO_2 level changes, and additionally examine the residual effect after KT removal on the time to minimum rSO_2 levels.

   Hypothesis 5: The acute KT application will change the time to minimum of muscle rSO_2 levels in the trial in the treatment leg flexors/extensors during the fatiguing isotonic knee flexion/extension exercise, the effect will be more prominent with duration of tape application, and additionally there will be a residual effect to maintain or change the time to minimum rSO_2 levels after KT removal.

   Hypothesis 5a: The time to minimum of rSO_2 levels in the trial will change after acute KT application.

   Hypothesis 5b: The time to minimum of rSO_2 levels in the trial will change due to duration of KT application.

   Hypothesis 5c: The residual effect after KT application will exist and change the time to minimum of rSO_2 levels in the treatment leg.

Table 1: Summary of the reviewed articles

Article Information				Article Topics							
	Authors	Date	Journal	KT Tape	Healthy Participant	Test with Legs	Case-control	Isotonic	Duration	Dynamometer	Muscle Oxygenation
1	Oscar M.H. Wong	2012	Physical Therapy in Sport	V	V	V				V	
2	T.C Fu	2008	Journal of Science and Medicine in Sport		V	V					
3	H.Y. Chang	2010	Physical Therapy in Sport	V	V						
4	Y. Konishi	2013	Journal of Science and Medicine in Sport	V	V	V				V	
5	K.Y. Poon	2015	Manual Therapy	V	V	V				V	
6	Y. Shah	2017	Journal of Bodywork and Movement Therapies	V	V						V
7	H. Preece	2016	Journal of Bodywork & Movement Therapies	V	V						
8	W. Moalla	2006	Journal of Sports Sciences		V	V				V	V
9	J. H. van Dieen	2007	Journal of Electromyography and Kinesiology		V					V	V
10	J. Pliner	2015	Conference Paper	V	V	V	V	V		V	V
11	A. Ptak	2013	Journal of Back and Musculoskeletal Rehabilitation	V						V	
12	H.B. Gak	2011	International Journal of Occupational Medicine and Environmental Health	V	V		V				
13	E. Kaya	2010	Clinical Rheumatology	V			V				
14	A. Luque-Suarez	2014	Physiotherapy	V							
15	M. Gart	2016	Hand Clinics	V	V		V				
16	H.J. Tsai	2009	Support Care Cancer	V	V		V		V		
17	C.Y. Huang	2011	BioMedical Engineering OnLine	V	V	V	V				
18	A. Ibrahim	2015	International Journal of Therapies and Rehabilitation Research	V		V	V		V	V	
19	A.K. Burton	1996	Spine								

20	K. Kase	2003	Clinical Therapeutic Applications of The KinesioTaping Method	V		V					
21	K. MacGregor	2005	Journal of Orthopaedic Research	V		V					
22	H.J. Knapman	2016	Physical Therapy in Sport	V	V		V			V	
23	M.H. Lee	2011	Journal of Physical Therapy Science	V	V						
24	A.R. Soylu	2011	Med Sport.	V	V						
25	I. Vithoulk	2010	Isokinetics and Exercise Science	V	V						
26	A. Słupik	2007	Orto Traum Rehab.	V	V						
27	A. Yoshida	2007	Res Sport Med.	V	V						
28	G. Aktas	2011	Isokinetics and Exercise Science	V	V		V				
29	J.H. Lee	2010	Journal of Physical Therapy Science	V	V						
30	J. González-Iglesias	2009	Journal of Orthopaedic & Sports Physical Therapy	V			V				
31	J.T. Han	2014	Journal of Physical Therapy Science	V	V						
32	A.M. Castro-Sánchez	2012	Journal of Physiotherapy	V			V		V		
33	C.A. Fahs	2014	Clinical Physiology and Nuclear Medicine		V	V				V	V
34	M. Nakajima	2013	The International Journal of Sports Physical Therapy	V	V						
35	S. Semple	2012	Journal of Physical Therapy Science	V	V					V	
36	D. Duracoglu	2005	Journal of Clinical Rheumatology			V	V		V	V	
37	S. Bicici	2012	The International Journal of Sports Physical Therapy	V				V	V		
38	M. Gramatikova	2016	Sport Science	V		V	V		V		
39	S. Zhang	2016	Journal of Science and Medicine in Sport	V	V		V			V	
40	K. Briem	2011	Journal of Orthopaedic & Sports Physical Therapy	V							
41	C.A. Shields	2013	American Orthopaedic Foot & Ankle Society	V							
42	K.Y. Lee	2011	International Journal of Precision Engineering and Manufacturing		V			V			
43	D. DeLorey	2004	The Physiological Society		V	V					V
44	J. Simon	2014	Clinical Journal of Sport Medicine	V			V			V	
45	S. Fayson	2013	Research in Sports Medicine	V	V						
46	K. Jackson	2016	Journal of Athletic Training	V							

47	S. Ruggiero	2017	Journal of Sports Sciences	V	V						
48	M. Thelen	2008	Journal of Orthopaedic & Sports Physical Therapy	V			V		V		
49	T. Halseth	2004	Journal of Sports Science and Medicine	V	V						
50	C.A.A. Lins	2013	Manual Therapy	V	V		V			V	
51	G. Strutzenberger	2015	Europe Journal of Sports Science	V	V				V		
52	E. Akbas	2011	Acta Orthopaedica et Traumatologica Turcica	V					V		
53	A. Cheng	2005	Journal of Applied Physiology		V	V		V		V	
54	S. Álvarez-Álvarez	2014	Journal of Back and Musculoskeletal Rehabilitation	V	V						
55	G. Llopis	2012	Fisioterapia	V					V		
56	M. Paoloni	2011	Europe Journal of Physiology Rehabilitation	V					V		
57	A. Aystar	2011	Isokinetics and Exercise Science	V						V	
58	M. Saavedra-Hernandez	2012	Journal of Orthopaedic & Sports Physical Therapy	V					V		
59	C.T. Tsai	2010	Journal of Musculoskeletal Pain	V			V		V		
60	H.H Simsek	2013	Acta Orthopaedica et Traumatologica Turcica	V					V	V	
61	Y.H. Hsu	2009	Journal of Electromyography and Kinesiology	V							

Chapter 2: Methods

The University of Wisconsin-Milwaukee Institutional Review Board approved all the study materials and protocols in this research. (Protocol #15.372). All experimental sessions were conducted at the University of Wisconsin-Milwaukee Spine Biomechanics Laboratory (USRB 289).

2.1 Subjects

Fourteen healthy male college students volunteered to participate in this project and signed a consent form prior to testing. The subjects ranged in height and weight which averaged 182.9 ± 5.1 cm and 76.52 ± 10.2 kg respectively. Subjects were asked whether they had a leg injury in the past six months, or if they had ever sustained any other serious injury. Individuals who had a recent leg injury or an injury that would prevent them from performing the knee flexion/extension protocol optimally were excluded from the test.

The study protocol was explained to the subjects upon arrival and they were asked to conduct their normal daily activities during the entire testing duration (8 days). The dominancy was determined by asking the subjects which leg they use to kick a ball.

2.2 Experiment Design

An eight-day case-control study was designed to examine the effect of KT on a knee joint isotonic flexion/extension fatigue protocol. Commercially available “Kinesio-Tape” brand KT was used in this study (Figure 1). All data was collected bilaterally (left and right knee) following the same protocol over eight consecutive days. The overview of the experimental design is presented in Table 2.

Figure 1: Kinesio-Tape (KT)

retrieved from: https://www.kttape.com/kt-tape-pro-kinesiology-tape

During the experiment no KT was applied to the subject's non-dominant leg (control leg). The dominant leg (treatment leg) was left untaped (nKT) for the first two days. The KT was applied on Day 3 and was kept on through Day 6. The KT was then removed. The final two testing sessions were conducted 24 hours after KT removal (Days 7 & 8). Testing with no KT application on Day 1 was used as a "training" session and was not used for analysis. The data from Day 2 to Day 8 was used to establish individual performance differences with and without KT, as well as for the assessment of potential "learning" effect (K. Jackson et al., 2016; J.T. Han et al., 2014; C. Fahs et al., 2015).The test began at the same time every day (± 2 hours), in order to eliminate any potential influence of time of day on performance. The start time was determined by the start of testing on the first day (H. Chtourou et al., 2012).

Table 2: Experimental design schedule overview

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
Treatment leg	nKT		KT				nKT	
Control Leg	nKT							

On Day 3 of the protocol, KT was applied to the dominant knee per the manufacturer's protocol (Kase, 2003). KT placement, and subsequent sensor placement, was conducted by the same researcher each day for all subjects to avoid any error due to differing techniques of multiple researchers. The following outcome parameters of interest were considered and are described in more detail in the subsequent sections:

Rate = number of cycles (flexion/extension) per second

Time to fatigue (TTF) = time to the point that the subject could no longer perform the task

rSO_2 = percent of muscle oxygenation

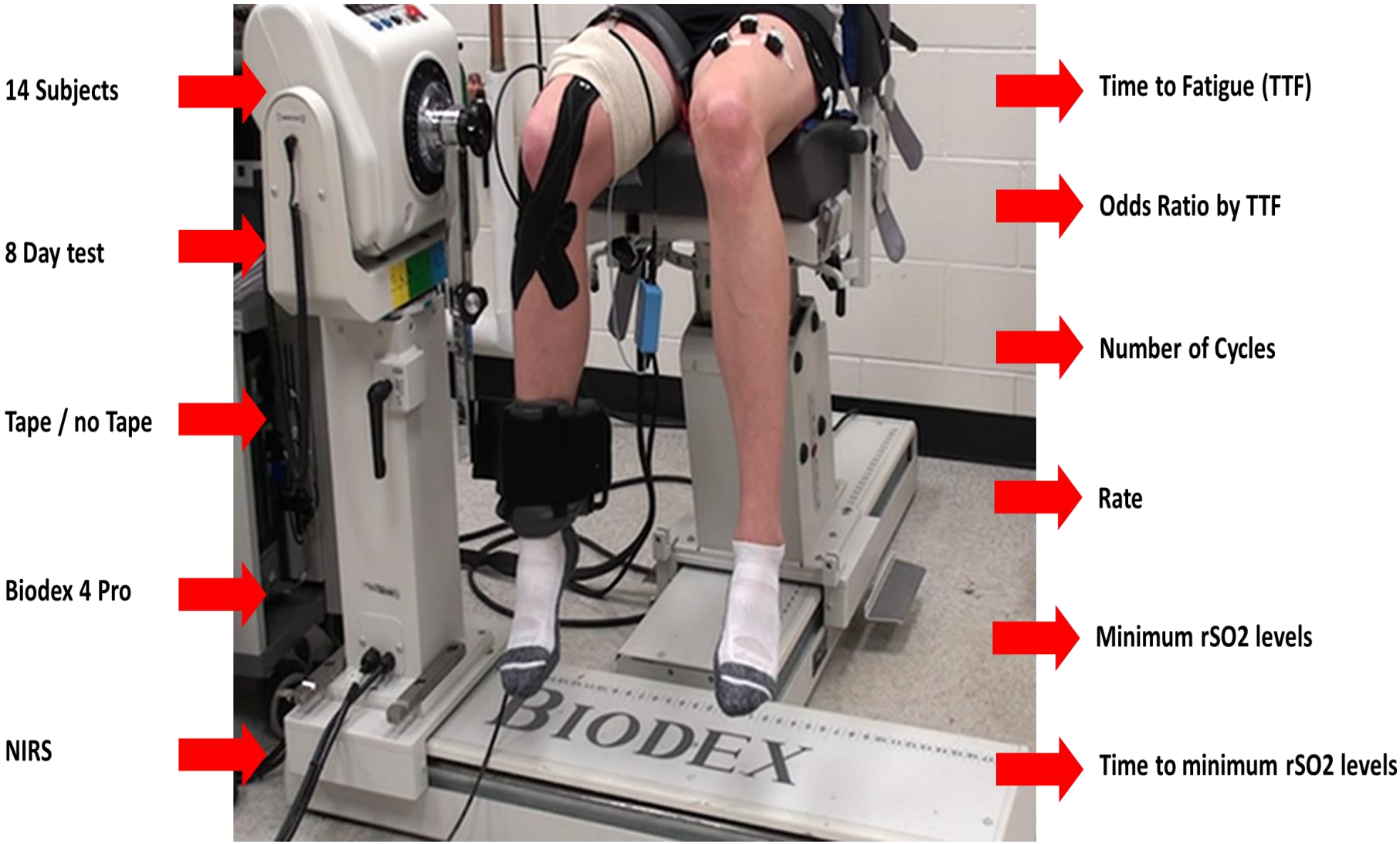

Figure 2: The isotonic flexion/extension experiment input and output variables

2.3 Equipment and Data Collection

2.3.1 Biodex

The knee flexion/extension exercise was recorded using a Biodex dynamometer System 4 (Biodex Medical Systems, NY).

Figure 3: Subject's initial position on Biodex

Subjects were strapped down on the positioning chair with two seatbelts. One belt was positioned across the chest, and another belt was tied on the tested leg as depicted in Figure 3. The isotonic test was administered for knee flexion and extension exercises with the resistant load set at 40 pounds and no velocity control. The initial position of the knee was set at 90-degree flexion angle.

The data was recorded at 100 Hz and included joint position, velocity, number of cycles and duration of the task. Time to fatigue (TTF) and the rate (calculated by number of cycles over TTF) were the main biomarkers of interest during each testing

session.

The TTF was used to calculate the odds ratio (OR) to describe the association between acute KT application and time to fatigue. Table 3 and Equation 1 explain the calculation of the odds ratio, including the parameters required for each leg. The odds ratio result was determined by the scale presented in Figure 4.

Table 3: TTF performance odds ratio table

TTF	Treatment leg	Control Leg
TTF Increased	a	b
TTF Not Increased	c	d

$$Odds\ ratio = \frac{a/c}{b/d} \qquad Eq\ 1$$

a = number of subjects with increased TTF on the treatment leg

b = number of subjects with increased TTF on the control leg

c = number of subjects with no increase in TTF on the treatment leg

d = number of subjects with no increase in TTF on the control leg

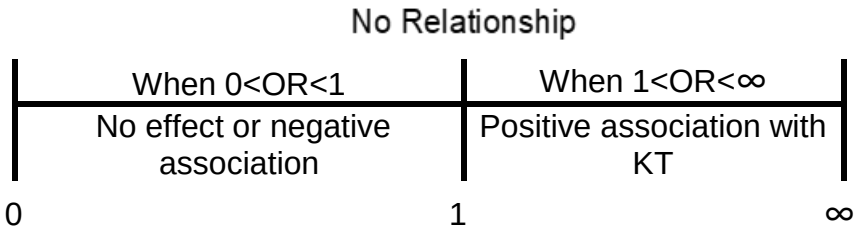

Figure 4: Odds ratio scales

The relative risk (RR) considered the time factors. Therefore, relative risk was calculated to examine the effect of duration of KT application (after 24 hours, 48

hours, and 72 hours of wearing). Table 4 and Equation 2 explain the calculation of the relative risk, including the parameters required for each leg. The relative risk result was determined by the scale presented in Figure 5.

Table 4: TTF performance relative risk table

TTF	TTF Increased	TTF Not Increased
Treatment leg	a	b
Control Leg	c	d

$$Relative\ risk = \frac{a/(a+b)}{c/(c+d)} \qquad Eq\ 2$$

a = number of subjects with increased TTF on the treatment leg

b = number of subjects with no increase TTF on the treatment leg

c = number of subjects with increase in TTF on the control leg

d = number of subjects with no increase in TTF on the control leg

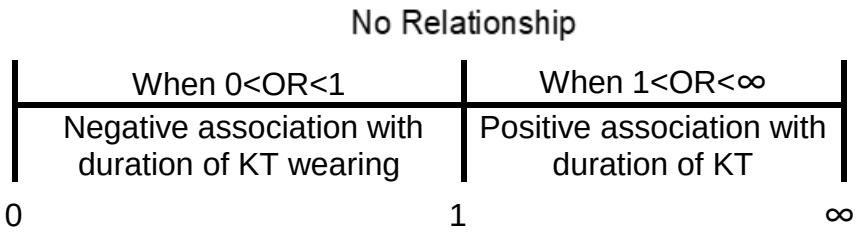

Figure 5: Relative risk scales

The rate of knee flexion/extension was calculated by dividing the total number of cycles by time to fatigue or total task time (Eq 3). All three parameters are related, and to determine the true meaning of any changes all three must be considered. For example, TTF may increase, but if no change occurred in the number of cycles, it

means that the velocity decreased and therefore the change may not be biomechanically significant.

$$Rate = \frac{Number\ of\ Cycles}{Time\ to\ Fatigue} \qquad \textit{Eq 3}$$

As with TTF, odds ratio and relative risk were used to discuss the acute KT application and the duration of KT wearing.

The percent change of TTF and rate was calculated to normalize the data and unify the scale. The percent change is necessary when discussing the comparison between legs (Eq 4), since the percent change explains the TTF or rate data increase or decrease more directly (Eq 5, Eq 4).

$$Percent\ Change\ in\ TTF = \frac{TTF\ Day_i}{TTF\ Day_2} \qquad i = 3,4,5,6,7,8 \qquad \textit{Eq 4}$$

$$Percent\ Change\ in\ Rate = \frac{Rate\ Day_i}{Rate\ Day_2} \qquad i = 3,4,5,6,7,8 \qquad \textit{Eq 5}$$

2.3.2 Near-infrared spectroscopy (NIRS): The EQUANOX 7600 (Nonin Medical Inc., MN) two channel Near Infrared System (NIRS) was used to measure the regional muscle oxygen saturation (rSO_2) and is shown in Figure 6. Two sensors were placed on the Vastus Lateralis (VL) and Vastus Medialis (VM) muscles, which are the two largest muscles of the quadriceps muscle group as depicted in Figure 7. Before placing the electrodes, the sensor placement area was cleaned with alcohol, and after placement the sensors were secured with a bandage to prevent movement.

NIRS data was recorded at a rate of 0.25 Hz and was represented as percent of rSO_2 at any given time. The rSO_2 recordings during the fatiguing isotonic knee flexion/extension exercise testing session were taken continuously from the

beginning to the end. The NIRS data normalization was done as follows:

$$Normalized\ rSO_2 = \frac{rSO_2\ levels\ on\ Day\ i}{rSO_2\ levels\ at\ the\ beginning\ of\ trial\ on\ Day\ i}$$

$$i = 1,2,3,4,5,6,7,8 \qquad \textit{Eq 6}$$

After normalizing the data, the trends and the minimum rSO_2 level were extracted for each trial. Instead of using the time when the minimum drop occurred to determine time to fatigue, the percentage of the TTF previously described was calculated for further analysis (Eq 7).

$$Percentage\ of\ TTF\ to\ minimum\ rSO_2\ levels = \frac{Time\ to\ minimum\ rSO_2\ \ Day_i}{TTF\ Day_i}$$

$$i = 1,2,3,4,5,6,7,8 \qquad \textit{Eq 7}$$

Figure 6: The NIRS system

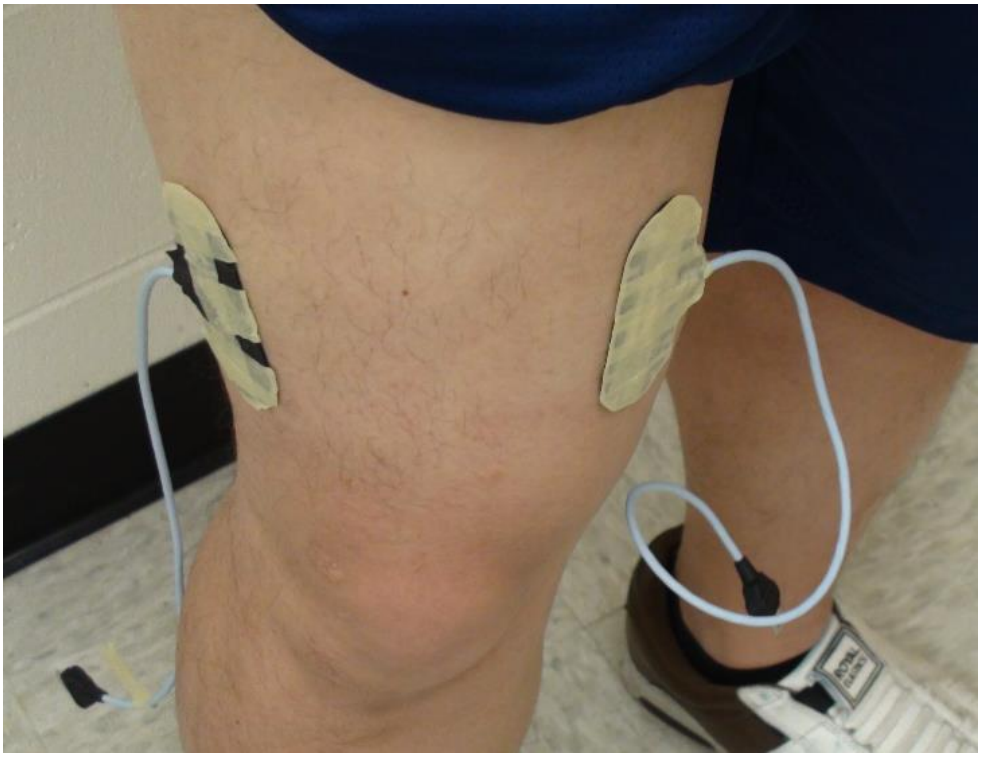

Figure 7: NIRS sensor placement

2.3.3 Video recording:

All the experiments were recorded using a standard digital video camera (Sony, Japan) in order to visually assess the subjects' performance. Some subjects did not perform full cycles at the end of their trial and the video recording combined with Biodex leg positioning data were used to determine the exact TTF and number of cycles.

2.5 Analysis

2.5.1 Statistical Analysis

One of the methods that could assess the outcome performance in this research is the trend from Day 2 to Day 8 in TTF and rate response. The slope in

time series could explain the trend rising or descending; the equation below is the time series (Eq 8). The time series can forecast future performance, and check the data point trends already collected (C. Chatfield, 2016; D. Montgomery, 2015). Time series analysis is commonly used in economic and biology studies. The coefficient β is the slope of the trend, and the β comparison calculated by paired t-test indicates how the exercise performance changes. Time series is used to investigate whether Hypothesis 1 and 2 are rejected or failed to reject.

$$Yt = y_0 + \beta * t \qquad t = Day\ 1, 2, 3, \dots\dots, \infty \qquad \textit{Eq 8}$$

β = The slope (coefficient) of the time series

y_0= Initial point of response

Yt= The forecasted response on Day t

The outliers were identified using Eqs 9-11.

$$IQR = Q_3 - Q_1 \qquad \textit{Eq 9}$$

$$Low\ Outlier\ Point = Q_1 - (1.5 \times IQR) \qquad \textit{Eq 10}$$

$$High\ Outlier\ Point = Q_3 + (1.5 \times IQR) \qquad \textit{Eq 11}$$

Interquartile Range: IQR

First Quartile: Q_1

Third Quartile: Q_3

Paired t-test was used for statistical analysis while keeping a subject as a block. Confidence was set at 95%. To answer the hypotheses a, D2 and D3 are compared to show the acute KT application effectiveness. The effect of KT

application duration will be interpreted by the comparison with D3 to 24 hours, 48 hours, and 72 hours (D4 to D6). To explain hypothesis c (residual effect), D7 compared to D6 and D2 will be calculated to evaluate the residual effect.

One-sided Wilcoxon sign tests were utilized for hypotheses 1 and 2 to answer whether the KT will enhance the TTF or rate performance, because both performance data are not normally distributed. On the other hand, Hypothesis 3 investigated whether or not the KT would increase the sitting baseline. Therefore, one-tailed paired t-test (sitting baseline data passed the normality test) has been selected in this study. Hypotheses 4 and 5 were assessed using a two-tailed paired t-test (minimum rSO_2 and time to minimum rSO_2 level in the trial data had to pass the normality test) because it is expected that KT will affect muscle oxygenation, but the direction is not clear in the influence of minimum rSO_2 levels and time to minimum rSO_2.

Chapter 3 Results

3.1 Fatiguing of Isotonic Knee Flexion Extension Exercise

3.1.1 Time to Fatigue (TTF):

Effects of KT were calculated by comparing the changes within TTF in the treatment and control leg of each subject across days of KT application. Performance could have either increased or not increased (no change between days or decreased both days). A subject was considered to have enhanced performance if there was an increase in the TTF only within the treatment leg. Comparisons between D3 and D2 captured the acute effects of KT; whereas, comparisons between D3 and D4-D6 investigated the effects of duration of KT application.

In this study, an enhancement in the treatment leg's performance occurred in only 2 subjects (14%) between D3 and D2 (Table 5). Nine of the 14 subjects' (64%) performance either increased or not increased in both legs. The odds ratio (OR) of 0.75 (Figure 8) indicates that the odds of observing an increase in TTF is less for the treatment leg than the control leg. Furthermore, the results (Figure 9) show that the subjects did not experience a statistically significant increase in TTF upon immediate application of KT (p=0.265).

Table 5: Number of subjects in each TTF response category based on acute KT application

Changes in TTF between D3 and D2	Number of subjects
Increased in both legs	5
No increase in both legs	4
Treatment leg increased	2
Control leg increased	3
Total subjects	**14**

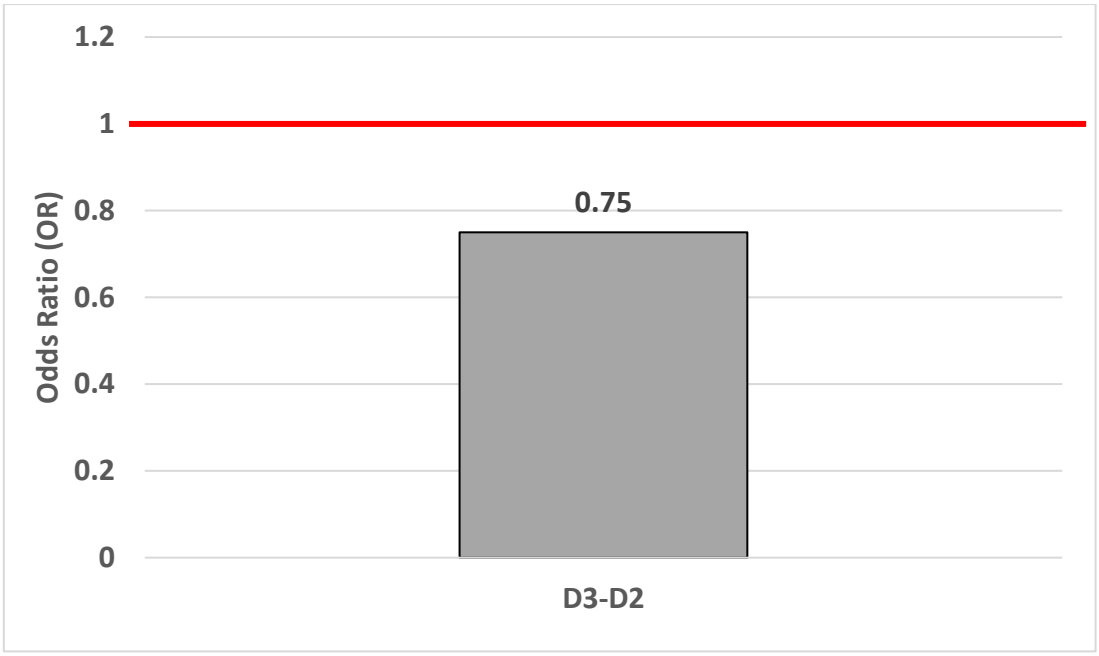

Figure 8: Odds ratio for association between treatment and control leg and changes in TTF based on acute KT application

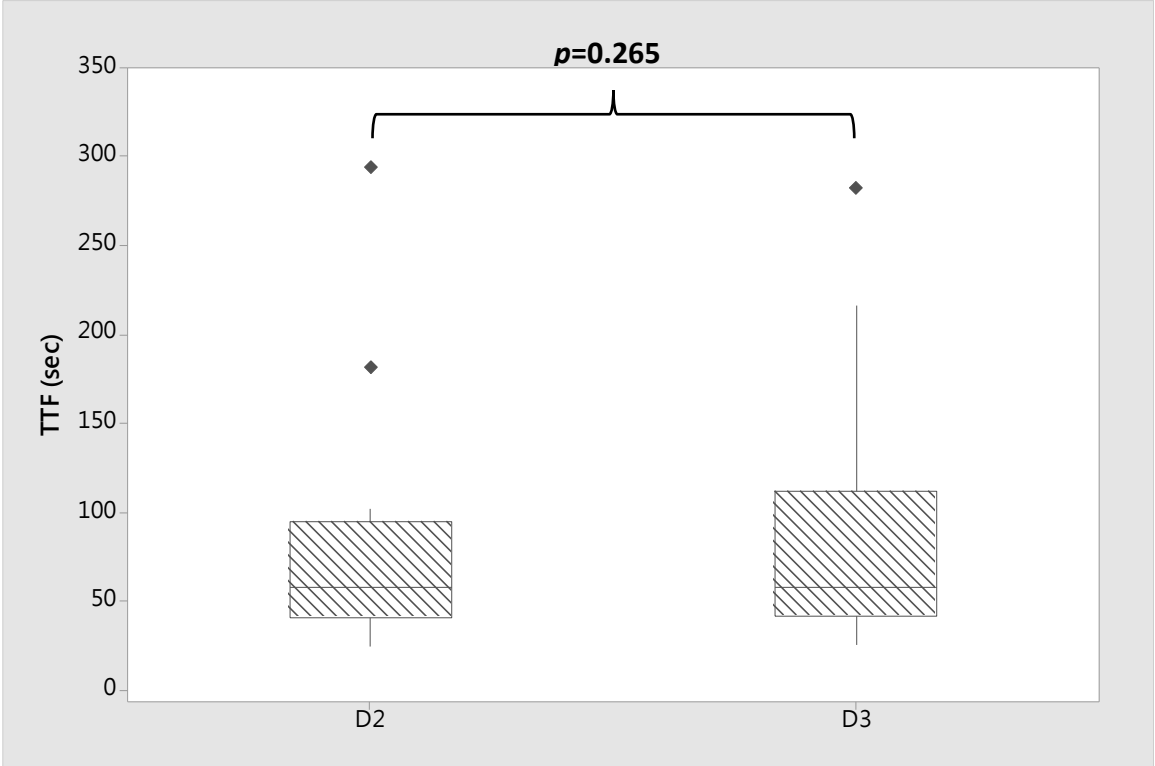

*Figure 9: The acute effect of KT application on TTF in the treatment leg. ♦ indicates an outlier. * indicates statistical significance between median TTF (indicated by horizontal line within bar) for D2 and D3*

The results for the duration of KT application are based on comparing leg performance between D3 and after 24 hours (D4), 48 hours (D5), and 72 hours (D6) of wearing KT (Figure 11). After 24 hours of KT application, within the treatment leg of 3 subjects, the TTF increased (21%). For 10 of 14 subjects (71%), the TTF either increased or not increased in both the treatment and control leg after 24 hours application of KT. No subject saw an enhancement only in the treatment leg 48 hours after KT application (D5). On this same day, similar performance (either increased or not increased) was noted for both legs in 86% of the subjects (12 of the 14 subjects). The results after 72 hours of KT application indicated that 9 of the subjects (64%) have a similar trend for both legs (either increased or not increased), and performance in 2 of the 14 subjects (14%) was better for the treatment leg but TTF decreased in the control leg. Table 6 quantifies the dose-response relationship between duration of KT application and leg performance. The relative risk shows that enhanced performance is more likely in the treatment leg only after 24 hours KT application (RR=1.286) (Figure 10). Statistical test results indicate no significant increase in TTF after 24 (p=0.235), 48 (p=0.063) or 72 hours (p=0.139) of KT application (Figure 11).

Table 6: Number of subjects in each TTF response category for each 24 hour period of KT application through D6 (72 hours after KT application)

Changes in TTF from D3	**Number of subjects**		
	D4-D3	**D5-D3**	**D6-D3**
Increased in both legs	6	9	6
No Increase in both legs	4	3	3
Treatment leg increased	3	0	2
Control leg increased	1	2	3
Total subjects	**14**	**14**	**14**

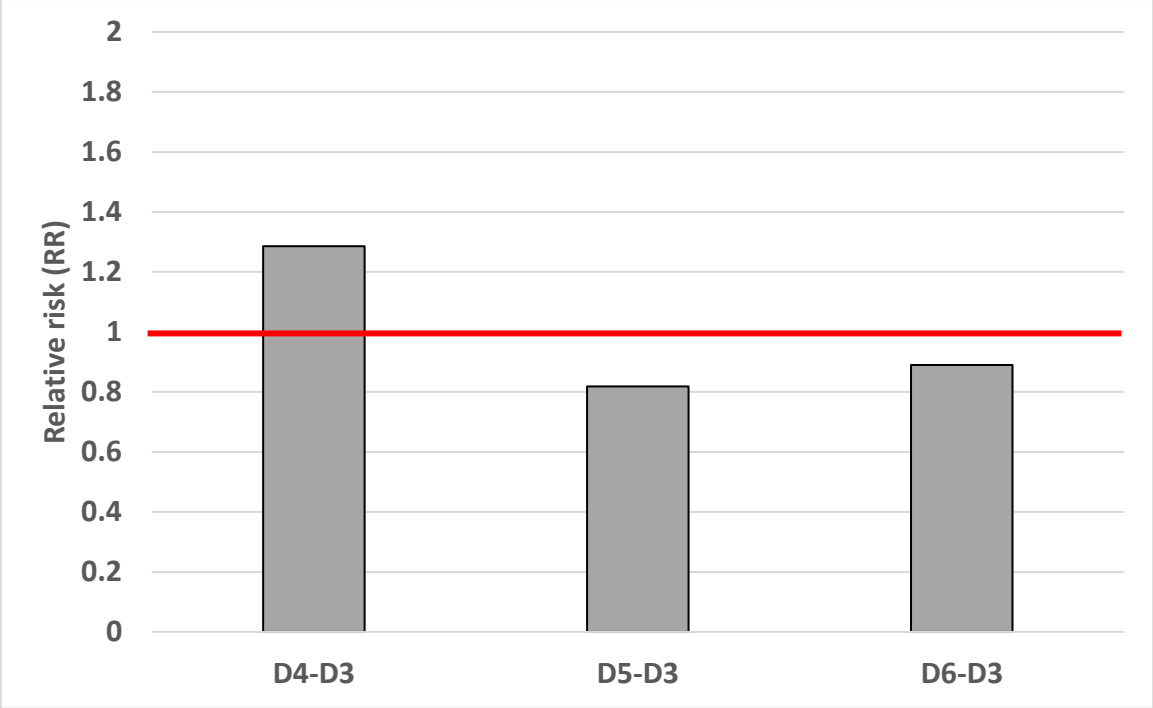

Figure 10: Relative risk for legs and changes in TTF based on the duration of KT application

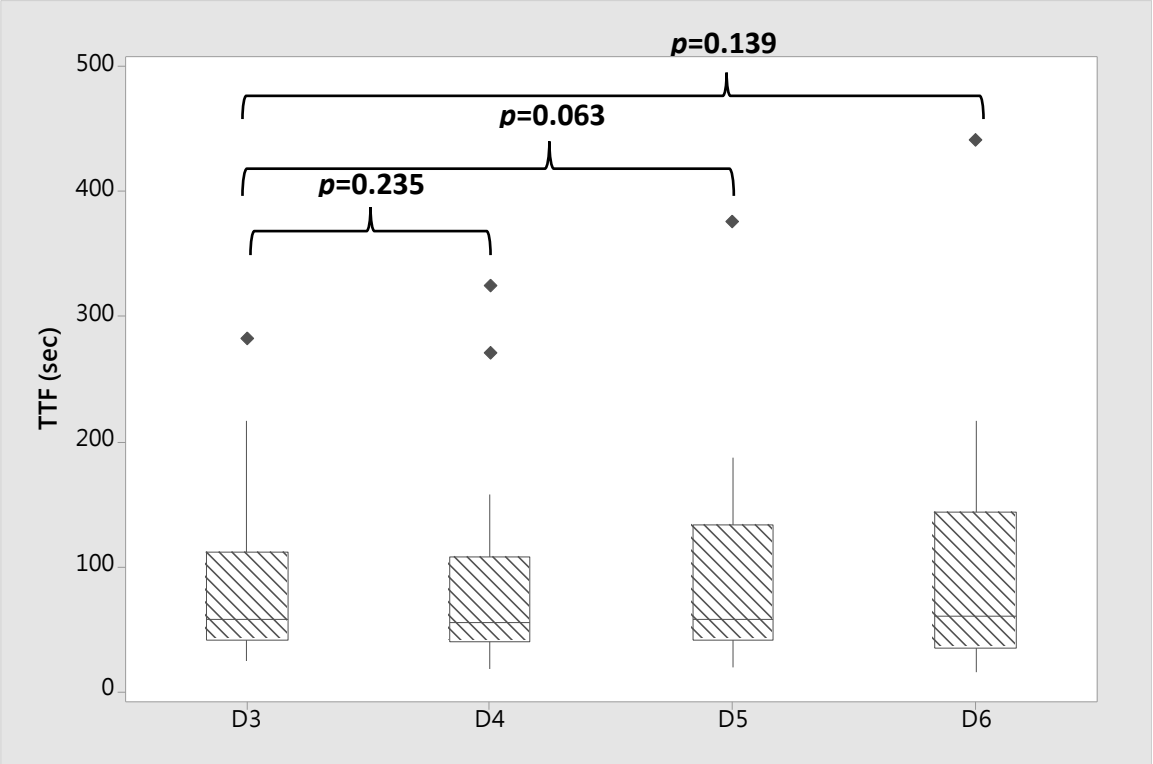

*Figure 11: Box plot of TTF throughout the duration of KT application in treatment leg. ♦ indicates an outlier. * indicates statistical significance between median TTF (indicated by horizontal line within bar) for D3 to D4, D5, D6*

Days 7 and 8 (24 and 48 hours after KT removed) were tested to consider the residual effects of KT, if any. No residual effects of KT were expected. In other words, The TTF was expected to have a decrease at 24 hours after tape was removed (D7 compared to D6) and observe similar results as those on D2. In the treatment leg on D7 to D2 and D7 to D6, the TTF marked increase on both days (D7 to D2: p=0.018, Power=99.6%) (D7 to D6: p=0.005, Power=92.5%). However, when D7 is compared with D6, 10 of 13 subjects' (77%) TTF increase/decrease at the same time, and 3 of the subjects might increase because of KT residual effect. In comparison of D7 to D2, 12 of 13 subjects' (92%) TTF increased/decreased in both legs at the same time. Furthermore, 10 of 13 subjects (77%) show TTF increased on both legs when compared with D2 (Table 7). Additionally, the control leg was used to support if the increase found for the treatment leg was due to a residual effect. D7 to D6 control leg comparison has insignificant increase (p=0.38, Power=38.0%), but TTF on D7 significantly increased when compared to D2 (p=0.005, Power=100.0%) (Figure 12).

Table 7: Number of subjects in the category of TTF changes based on the residual of KT application results. D7 (the day after 24 hours KT removed) compare to D6 (The last day of test with KT application), D2 (A day before KT application wearing)

Changes in TTF from D7	**Number of subjects**	
	D7-D6	**D7-D2**
Increased in both legs	7	10
No increase in both legs	3	2
Treatment leg increased	3	0
Control leg increased	0	1
Total subjects	**13**	**13**

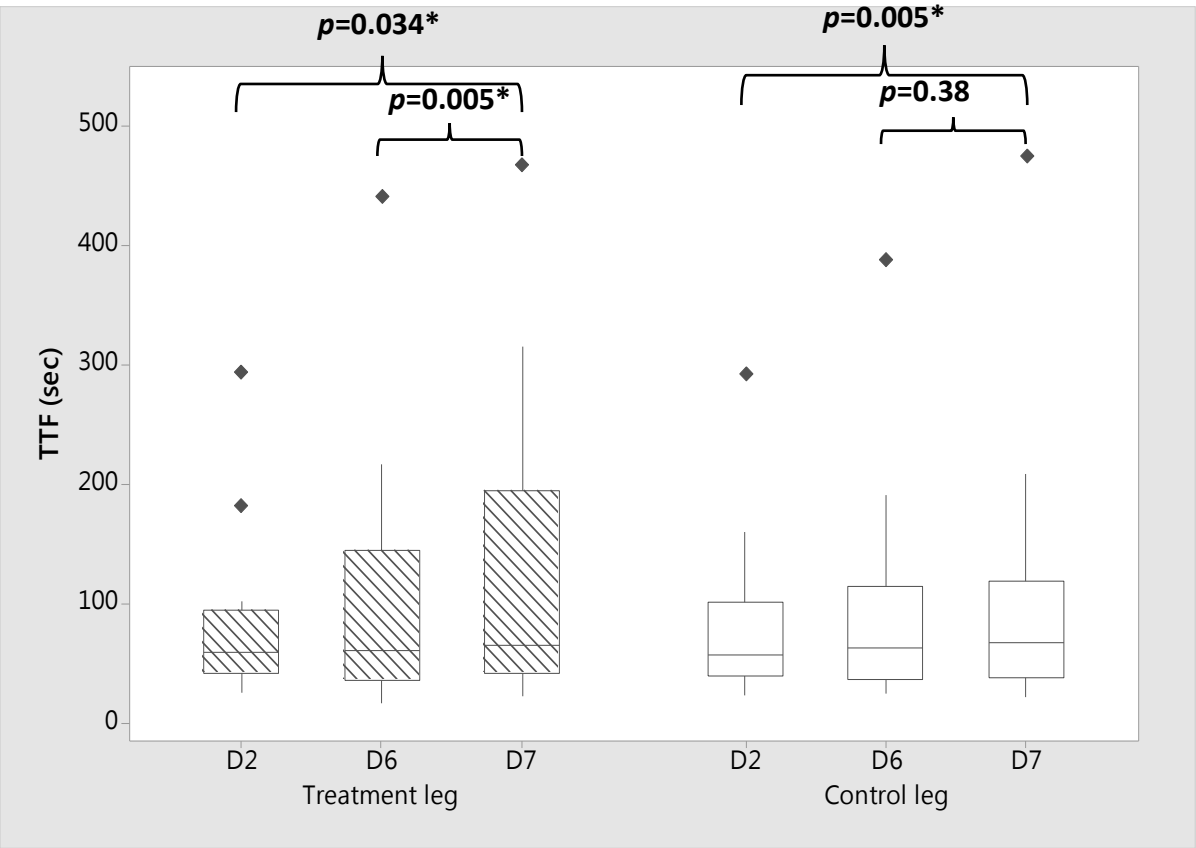

*Figure 12: Box plot showing the TTF on D2, D6, and D7 for both the control and treatment leg. ♦ indicates an outlier. * indicates statistical significance between median TTF (indicated by horizontal line within bar) for D7 compare to D6 and D2 in treatment leg and control leg*

The root cause of TTF increasing on D7 could be explained by comparing D2 to other days. The results indicate that both legs' TTF increased when extending the experiment day (Table 8). The most significant increase in treatment leg (p=0.005) and control leg (p=0.003) both happened on D5, which is also the day that both legs show the TTF significantly increased. Both the treatment leg and control leg results show that TTF significantly increased continuously from D5 to D8. According to the D2 comparison to other days' results, similar trends were shown in the treatment and control leg, and the time series could explain if the trend is caused by the learning effect.

Table 8: The results of Wilcoxon analysis in D2 (no KT effect) compare to D3 through D8 (the day with KT and after KT removed) to answer the residual effect of TTF is caused by KT or other factor.

Treatment Leg					Control Leg			
Compare to D2	Median Difference in TTF	Range in TTF	*p-value*	Power	Median Difference in TTF	Range in TTF	*p-value*	Power
D3	-2	20	*0.265*	33.6%	1	33	*0.550*	7.0%
D4	3	15	*0.062*	76.5%	5	20	*0.265*	63.1%
D5	10.5	28	*0.005* *	99.6% ▲	11.5	35.5	*0.003* *	100.0% ▲
D6	13.5	61	*0.021* *	89.6% ▲	14.25	79	*0.004* *	94.8%▲
D7	12	162	*0.034* *	99.6% ▲	12	37	*0.005* *	100.0% ▲
D8	7	45	*0.071*	65.3%	14	51.5	*0.012* *	99.1%▲

* indicates statistical significance between median TTF.
▲ presents the Power is greater than 80%

Time series analysis is another method to show any potential learning effect. According to the Time Series Equation (Eq 8), coefficient β represents the slope of the trend. The slope describes whether or not the change between two legs is the same. In this study, the paired t-test of the estimated slope parameters results (data table please refer to appendices Table A- 5) indicate that the changes in TTF data have no significant increases when comparing the control leg and treatment leg (p=0.165). As a result, the time series' slopes show that two legs have similar performance during the long-term fatiguing exercise experiment.

3.1.2 Rate of Flexion/Extension:

The acute KT application result in raw data (Table 9) shows that 5 of the subjects' (36%) rate increase might have been because of KT application when compared with Day 2 (before KT application). Either the rate increased or not increased in both legs for 6 of 14 subjects (43%) upon immediate application of KT (D3 compared to D2). Despite the raw data group showing that only 36% of subjects

may enhance the rate by acute KT application, the OR was 1.8 (Figure 13). *Figure 14* indicates that an increased rate was observed more in the treatment leg on D3 than in the control leg. The Wilcoxon test results (Figure 14) indicate a statistically significant increase in leg performance on Day 3 when compared to D2 (p=0.027), but note the low Power for this result.

Table 9: Number of subjects in each category of rate response based on acute KT application

Changes in rate between D3 and D2	**Number of subjects**
Increased in both legs	4
No increase in both legs	2
Treatment leg increased	5
Control leg increased	3
Total subjects	**14**

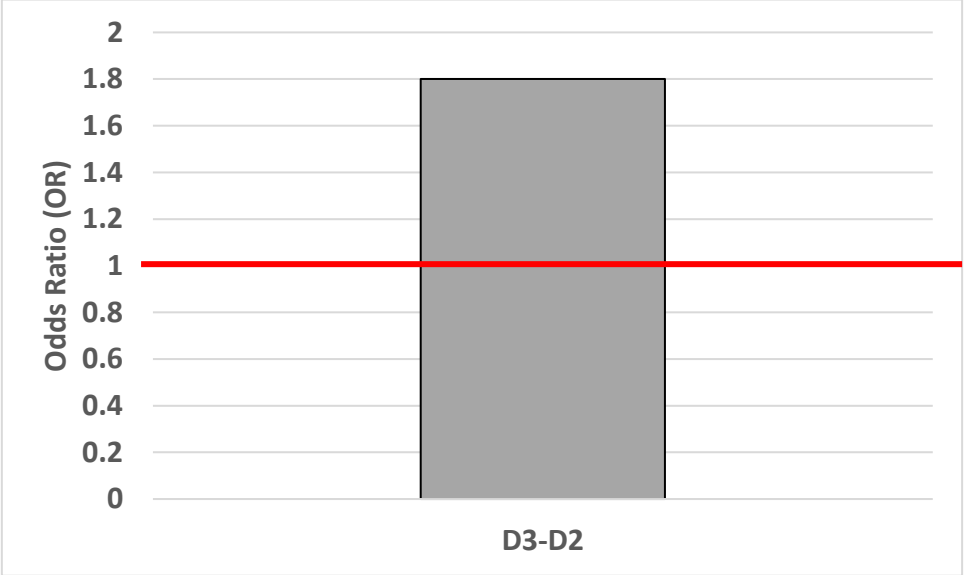

Figure 13: Odds ratio for association between treatment and control leg and changes in rate based on acute KT application

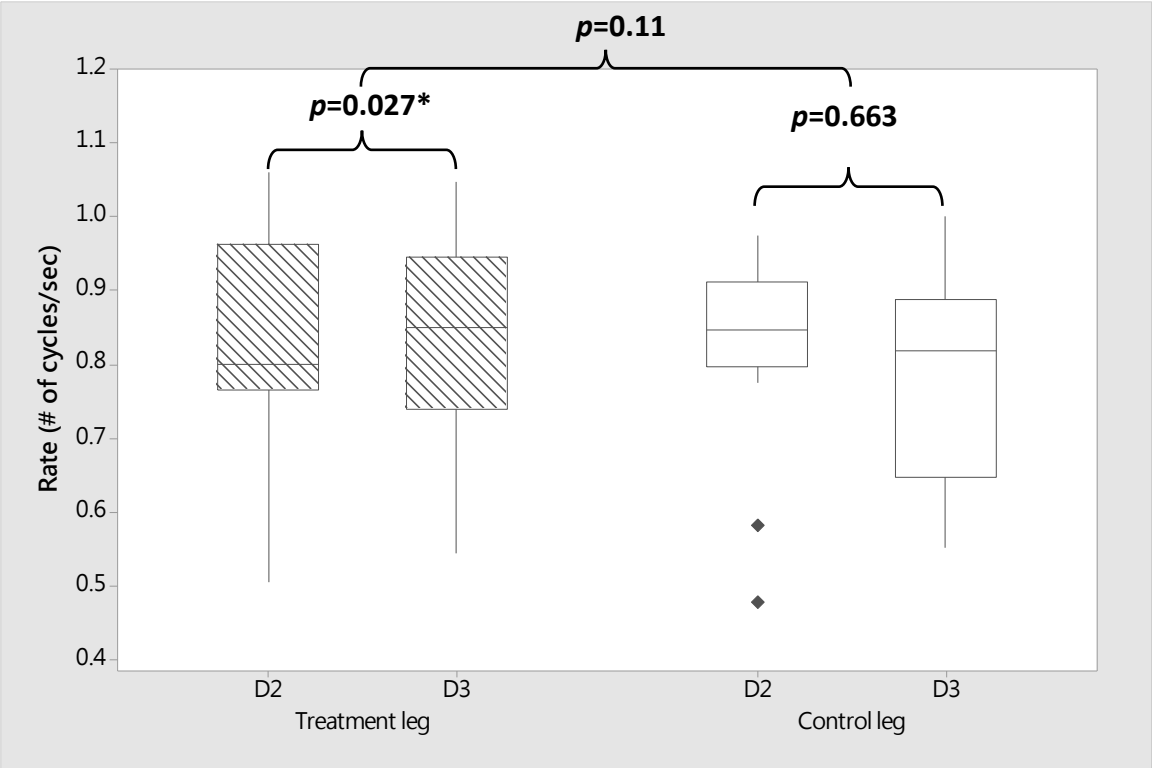

*Figure 14: Box plot of the rate on D2 and D3 for both the treatment and control legs. ♦ indicates an outlier. * indicates statistical significance between median Rate (indicated by horizontal line within bar) for D2 and D3*

Secondly, to assess the duration of KT application, Day 3 was selected to test the enhancement of rate after 24, 48, and 72 hours of KT application (Table 10). The rate increased in only the treatment leg of 1 subject 24 hours after KT application and either increased or not increased in both legs of 11 subjects (79%). After 48 hours of wearing KT, the rate increased in only the treatment leg for 2 of the 14 subjects (14%), and either increased or not increased in 8 of the subjects. A similar observation was noted 72 hours after KT application. Rate increased in the treatment leg in 2 subjects and either increased or not increased in 9 subjects. All the RR values are less than 1 (24 hours RR=0.875, 48 hours RR=0.818, 72 hours RR=0.89), indicating that an increased rate is less likely to occur in the treatment leg the longer the application of KT (Figure 15). These results are further supported by the Wilcoxon signed ranking test results (Figure 16). The subjects did not experience

a statistically significant rate increase in the duration of KT application (24 hours p=0.556, 48 hours p=0.094, 72 hours p=0.201).

Table 10: Number of subjects in each category of rate response for each 24 hour period of KT application through D6 (72 hours after KT application)

Changes in rate from D3	Number of subjects		
	D4-D3	D5-D3	D6-D3
Increased in both legs	6	7	6
No increase in both legs	5	1	3
Treatment leg increased	1	2	2
Control leg increased	2	4	3
Total subjects	**14**	**14**	**14**

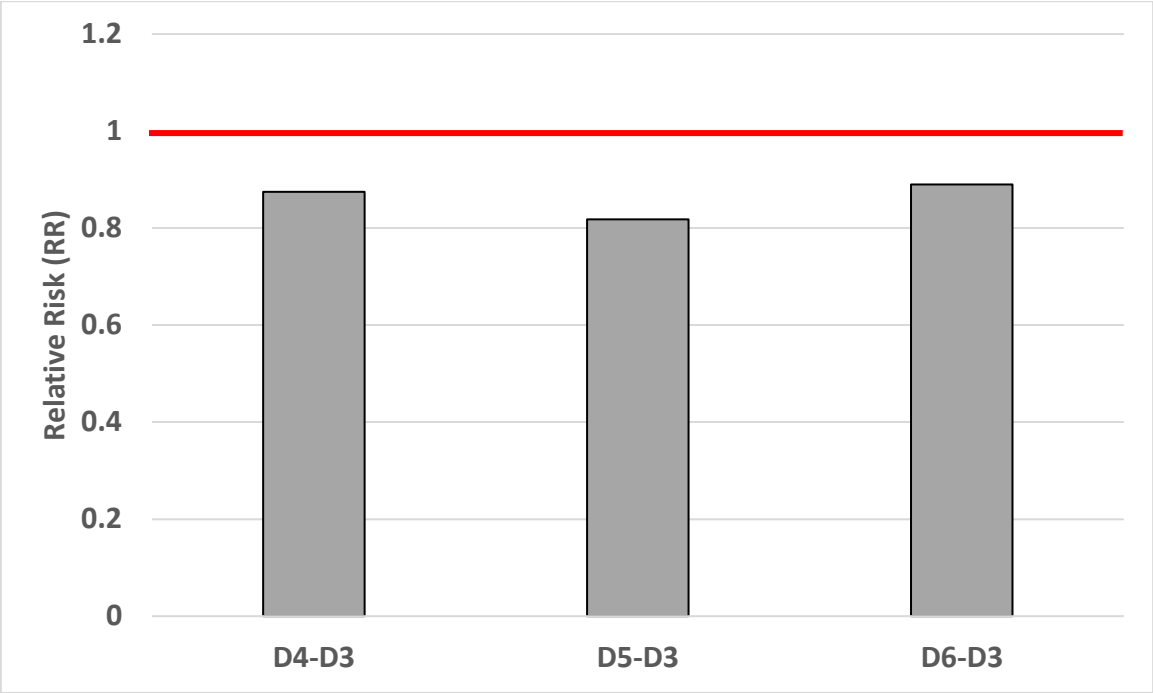

Figure 15: Relative risk for legs and changes in rate based on the duration of KT application

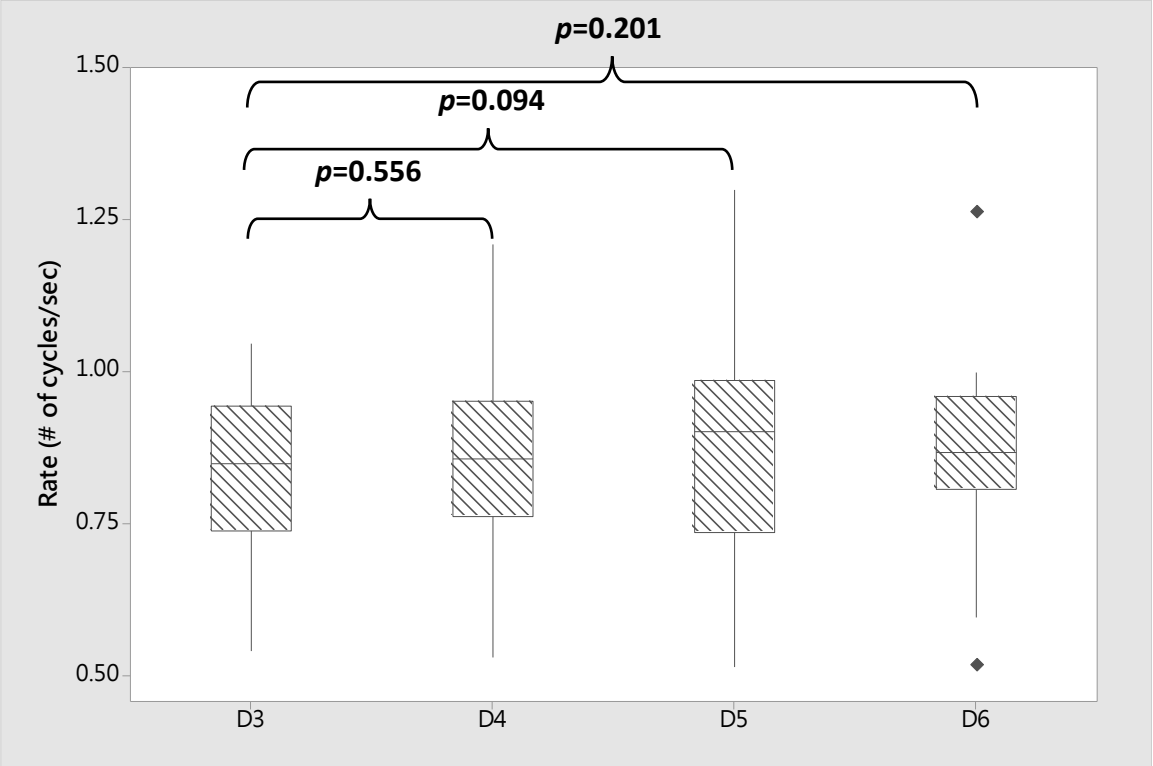

*Figure 16: Box plot of rate for D3, D4, D5, and D6. ♦ indicates an outlier. * indicates statistical significance between median Rate (indicated by horizontal line within bar) for D3 to D4, D5, D6*

The residual effect was tested by D7 compared to D6 and D2. The raw data result on D7 compared to D6 was expected to show the rate increased continuously or retained the same rate as D6. Results were collected for 13 of the 14 subjects. Table 11 depicts the results for these 13 subjects. In comparison to D2, 9 of the 13 subjects (69%) show that the rate either increased or not increased in both legs and increased only in the treated leg for 3 of the 14 subjects (Table 11). The Wilcoxon signed ranking test results present that after taking off the KT for 24 hours, there was no significant increase observed in rate when compared to D6 (p=0.447), and the median difference being 0 tells that the rate on D7 is similar to D6. From another point of view, the result on D7 compared with D2 (Figure 17) not only shows the rate statistically significantly increased (p=0.015), but also has 88.0% of Power to support that the increase truly exists. Therefore, the control leg was used to measure

whether the KT had a residual effect in rate on treatment leg.

Table 11: Number of subjects in each change in rate category based on the residual of KT application results. D7 (the day after 24 hours KT removed) compare to D6 (The last day of test with KT application), D2 (A day before KT application wearing)

Changes in rate from D7	**Number of subjects**	
	D7-D6	**D7-D2**
Increased in both legs	3	7
No increase in both legs	3	2
Treatment leg increased	3	3
Control leg increased	4	1
Total subjects	**13**	**13**

The control leg D7 compare to D6 (Figure 17) shows that the increase is statistically insignificant, which is similar to the treatment leg. In comparison of D7 to D2, Wilcoxon signed ranking test result present that D7 has a significant increase. However, the Power shows that it only has 63.4% chance of an increase in rate as a result of residual effect. Therefore, D2 compared to other days is evidence to explain the changes between D2 through D7.

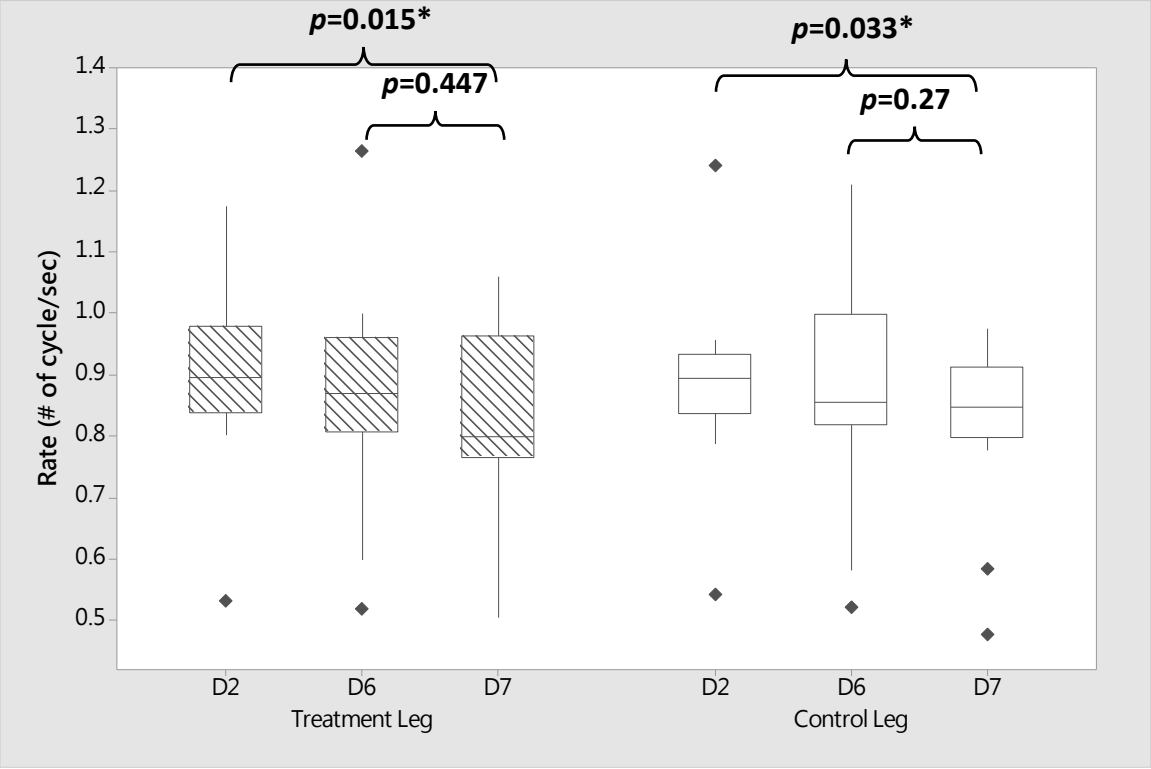

*Figure 17 : Box plot of rate for D2, D6, and D7 for both the treatment and control leg. ♦ indicates an outlier. * indicates statistical significance between median rate (indicated by horizontal line within bar) for D7 compare to D6 and D2 in treatment leg and control leg*

For D2 compared to other Days' results, both the treatment leg (p=0.008) and control leg (p=0.018) have the smallest p on D7. The treatment leg Power begins to be greater than 80% from D7 (Power=91.8%). Nevertheless, the control legs' largest Power is on D7 and is equal to 71.7%. According to the trends in the two legs, the rate is increasing every day (Table 12) for both. Hence, the last step is to show whether the rate increase is due to KT or another effect, and comparing the time series trends between legs could answer the question.

Table 12: The results of Wilcoxon analysis in D2 (no KT effect) compare to D3 through D8 (the day with KT and after KT removed) to answer the residual effect is caused by KT or other factor

Rate on D2 compare to other Days								
Treatment Leg					Control Leg			
Day	Median Difference in rate	Range in rate difference	*p-value*	Power	Median Difference in rate	Range in rate difference	*p-value*	Power
D3	0.039	0.239	*0.027**	66.9%	0.002	0.2	*0.663*	10.1%
D4	0.027	0.181	*0.046**	59.9%	0.015	0.162	*0.242*	18.0%
D5	0.032	0.322	*0.027**	65.1%	0.02	0.179	*0.147*	29.2%
D6	0.049	0.403	*0.021**	72.3%	0.023	0.137	*0.084*	35.5%
D7	0.066	0.349	*0.008**	91.8%▲	0.044	0.127	*0.033**	63.4%
D8	0.095	0.376	*0.008**	93.3%▲	0.057	0.259	*0.018**	71.7%

* indicates statistical significance between median rate
▲ presents the Power is greater than 80% and the p is truly significant

The same time series analysis that was performed on TTF was also done for rate. The time series analysis can assess if the treatment leg had better rate performance than the control leg. The results (data refer to appendices Table B- 5) show that there is an insignificant increase in rate (p=0.741). In addition, the Time Series' slope test shows that the two legs have similar performance during the long-term fatiguing exercise experiment.

3.2 Muscle Oxygenation

Every subject utilizes the muscles in a different way. In this study, 8 subjects have a rapid decrease in muscle oxygenation (rSO_2) for both legs at the beginning of the testing and slow recovery throughout the testing (Figure 34). The other subjects have a constant reduction in muscle oxygenation until the end of the trial.

3.2.1 Sitting baseline rSO_2 level:

Vastus Medialis (VM): The acute KT application result shows that 10 of 13

subjects (76.92%) had an increase in Sitting Baseline on D3 in comparison to D2 (Table 13). The OR=6.00 means that KT has a positive association with an increase in sitting baseline rSO_2 levels (Figure 18). The acute KT application did not significantly increase the sitting baseline rSO_2 levels on the treatment leg VM muscle (p=0.062) (Figure 19).

Table 13: Number of subjects in each category in VM muscle oxygenation sitting baseline based on acute KT application

Changes in VM muscle sitting baseline between D3 and D2	Number of subjects
Increased in both legs	5
Decreased in both legs	3
Treatment leg increase	5
Control leg increased	0
Total subjects	**13**

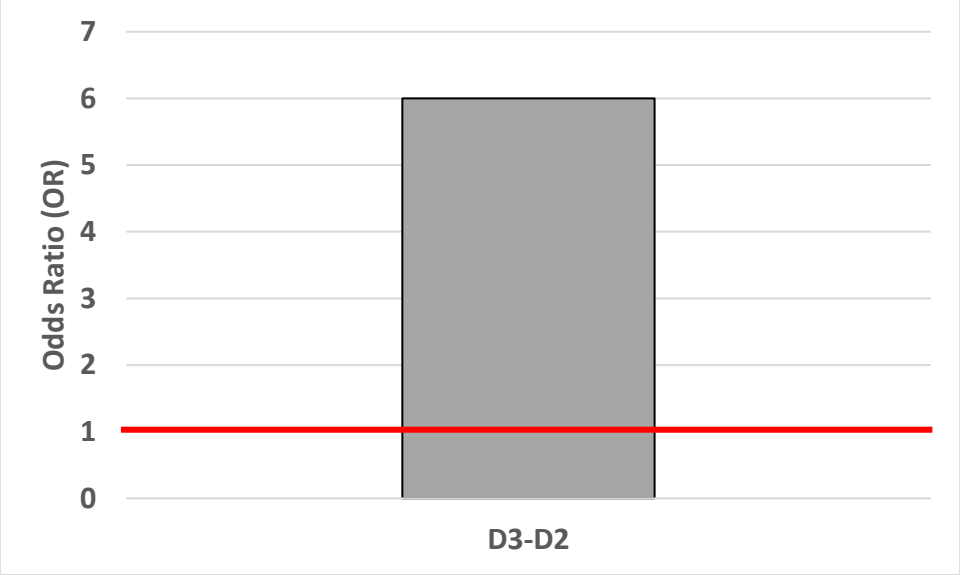

Figure 18: Odds ratio for association between the treatment and control leg VM muscles and changes in muscle oxygenation sitting baseline based on acute KT application

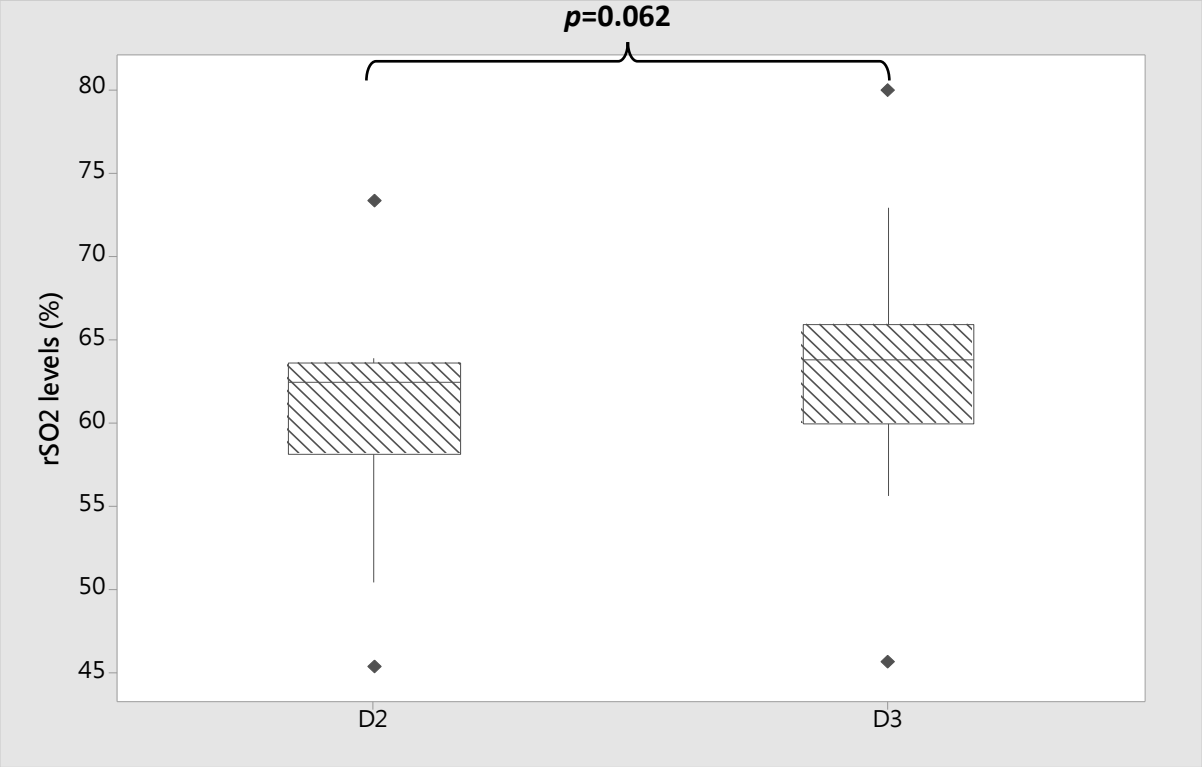

*Figure 19: Box plot of VM sitting baseline rSO_2 levels for D2 and D3 in the treatment leg. ♦ indicates an outlier. * indicates statistical significance between mean sitting baseline (indicated by horizontal line within bar) for D2 and D3*

Analysis regarding the duration of KT application (Table 14) revealed that 8 subjects' sitting baseline levels decreased on D4 from D3. By D5, 11 subjects' sitting baseline decreased (78.57%) from D3, but on D6 the subjects who decreased their sitting baseline went down to 10 (71.43%). Additionally, the RR provides evidence that extending the duration of KT application might not increase the sitting baseline rSO_2 levels, since the values are all less than 1 (D4-D3 RR=0.857, D5-D3 RR=0.333, D6-D3 RR=0.4) (Figure 20). Insignificant increases in treatment leg VM muscle sitting baseline (Figure 21) were observed when D3 was compared with other taped days (24 hours p=0.884, 48 hours p=0.993, 72 hours p=0.806). In addition, RR and mean difference in paired t-test results all show that the longer duration will decrease the sitting baseline rSO_2 levels in VM (RR all <1, mean difference <0).

Table 14: Number of subjects in each category of VM muscle sitting baseline response for each 24 hours period of KT application through D6 (72 hours after KT application)

Changes in VM muscle sitting baseline from D3	Number of subjects		
	D4-D3	D5-D3	D6-D3
Increased in both legs	3	2	3
Not increased in both legs	4	4	3
Treatment leg increase	3	1	1
Control leg increased	4	7	7
Total subjects	**14**	**14**	**14**

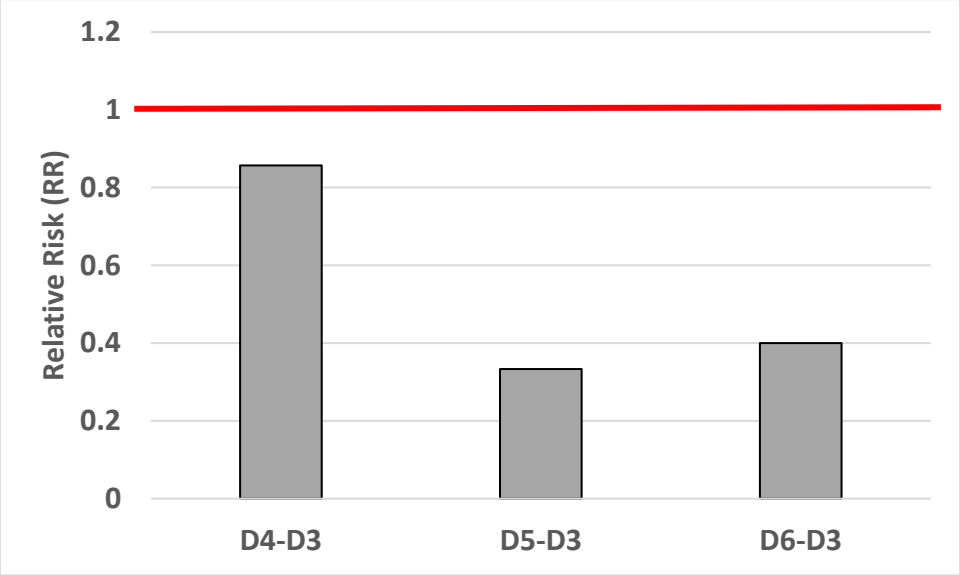

Figure 20: Relative risk for legs and changes in muscle oygenation sitting baseline based on the duration of KT application

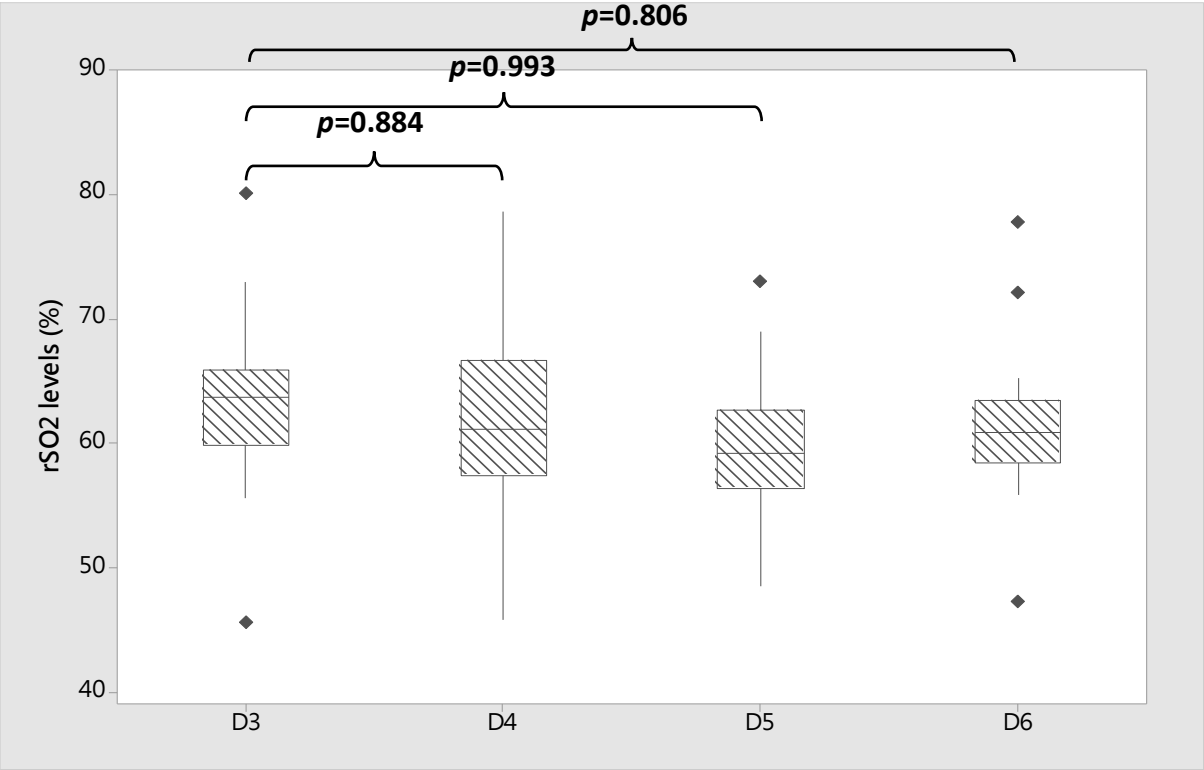

*Figure 21: Box plot of VM muscle oxygenation sitting baseline for D3, D4, D5, D6. ♦ indicates an outlier. * indicates statistical significance between mean muscle oxygenation sitting baseline (indicated by horizontal line within bar) for D3 to D4, D5, D6*

The residual effect from KT can be observed by analyzing D7. On D7, 9 of the subjects had both legs either increase the sitting baseline levels or did not increase their levels in comparison to D6 (Table 15). The comparison between D6 and D7 shows insignificant increase (p=0.399) (Figure *22*). Furthermore, there is no statistical difference between D7 compared with D2, which shows there is no residual effect (p=0.399).

Table 15: Number of subjects in each category of VM muscle oxygenation sitting baseline changes based on the residual of KT application results. D7 (the day after 24 hours KT removed) compare to D6 (The last day of test with KT application), D2 (A day before KT application wearing)

Changes in VM muscle sitting baseline from D7	**Number of subjects**	
	D7-D6	**D7-D2**
Increased in both legs	4	2
Not increased in both legs	5	3
Treatment leg increase	3	3
Control leg increased	1	4
Total subjects	**13**	**12**

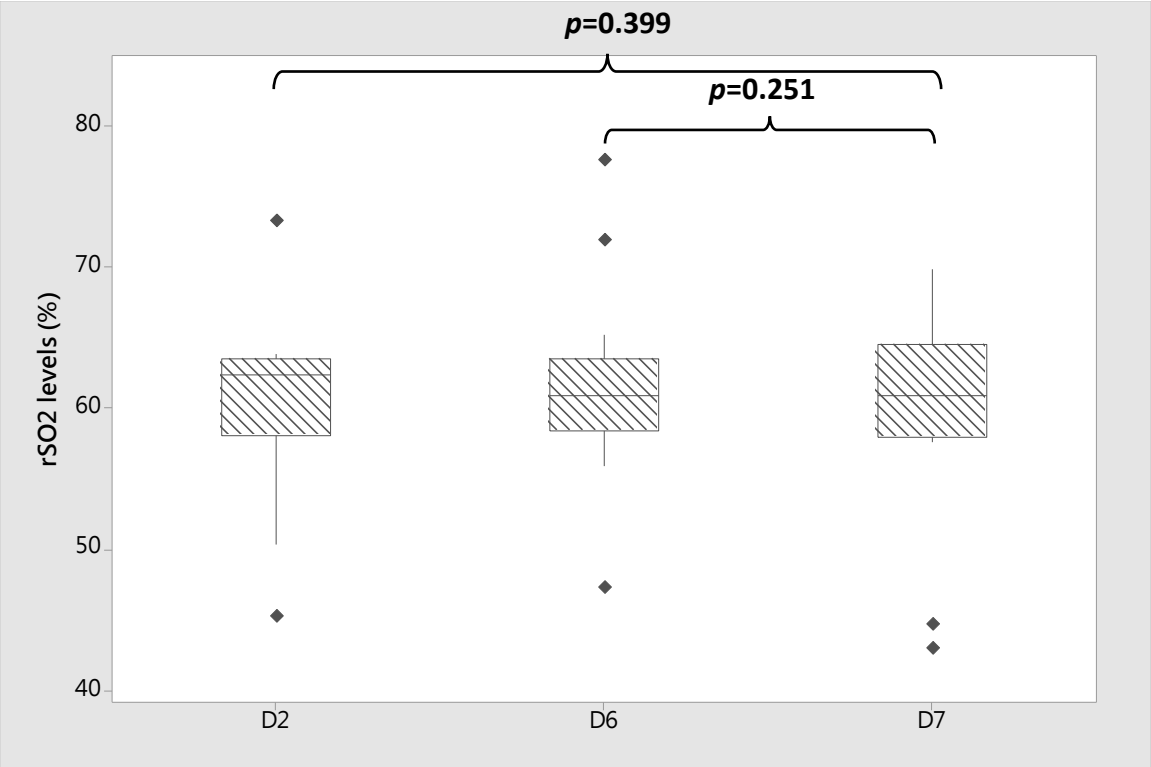

*Figure 22: Box plot of VM sitting baseline muscle oxygenation for the treatment legs on D2, D6, and D7. ♦ indicates an outlier. * indicates statistical significance between mean VM muscle oxygenation sitting baseline (indicated by horizontal line within bar) for D7 compare to D6 and D2 in treatment leg VM muscles*

Vastus Lateralis (VL): The results from acute KT application on D3 shows that 9 of 14 subjects (69%) increase or did not increase in both of their legs at the same time in comparison to D2. 23% of subjects VL sitting baseline increased from D2 only on the treatment leg (Table 16). The OR indicates that the acute KT application is associated with VL sitting baseline increase (OR=2.13) (Figure 23). The comparison of D3 to D2 in treatment leg VL muscle shows that there is a statistically significant increase in sitting baseline rSO_2 levels with acute KT application (p=0.045), but the Power of the test shows only 64.155% chance of an increase in VL sitting baseline as a result of acute KT application (Figure 24, Table C- 4).

Table 16: Number of subjects in each category of VL muscle oxygenation sitting baseline changes based on acute KT application

Changes in VL muscle sitting baseline between D3 and D2	Number of subjects
Increased in both legs	5
Not increased in both legs	4
Treatment leg increased	3
Control leg increased	1
Total subjects	**13**

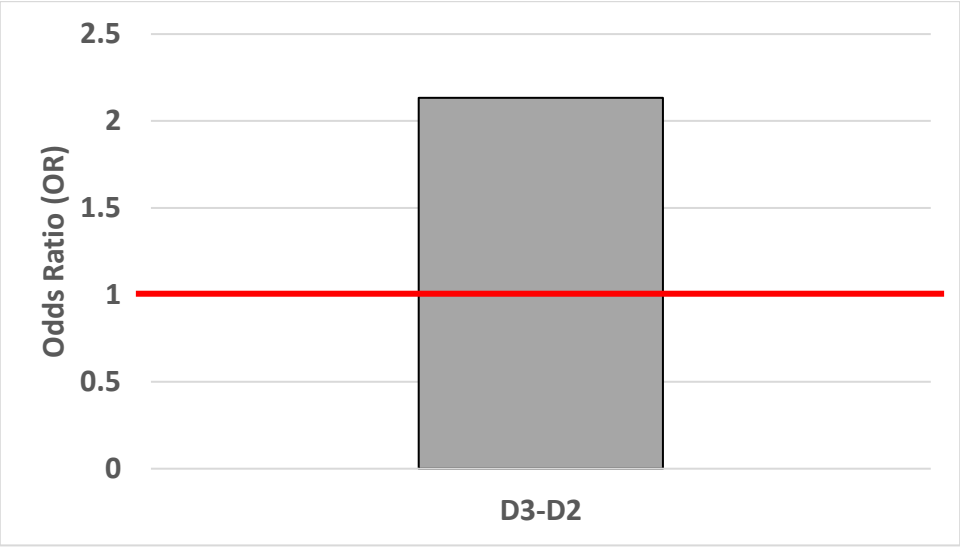

Figure 23: Odds ratio for association between treatment and control leg and changes in VL muscle oxygenation sitting baseline based on acute KT

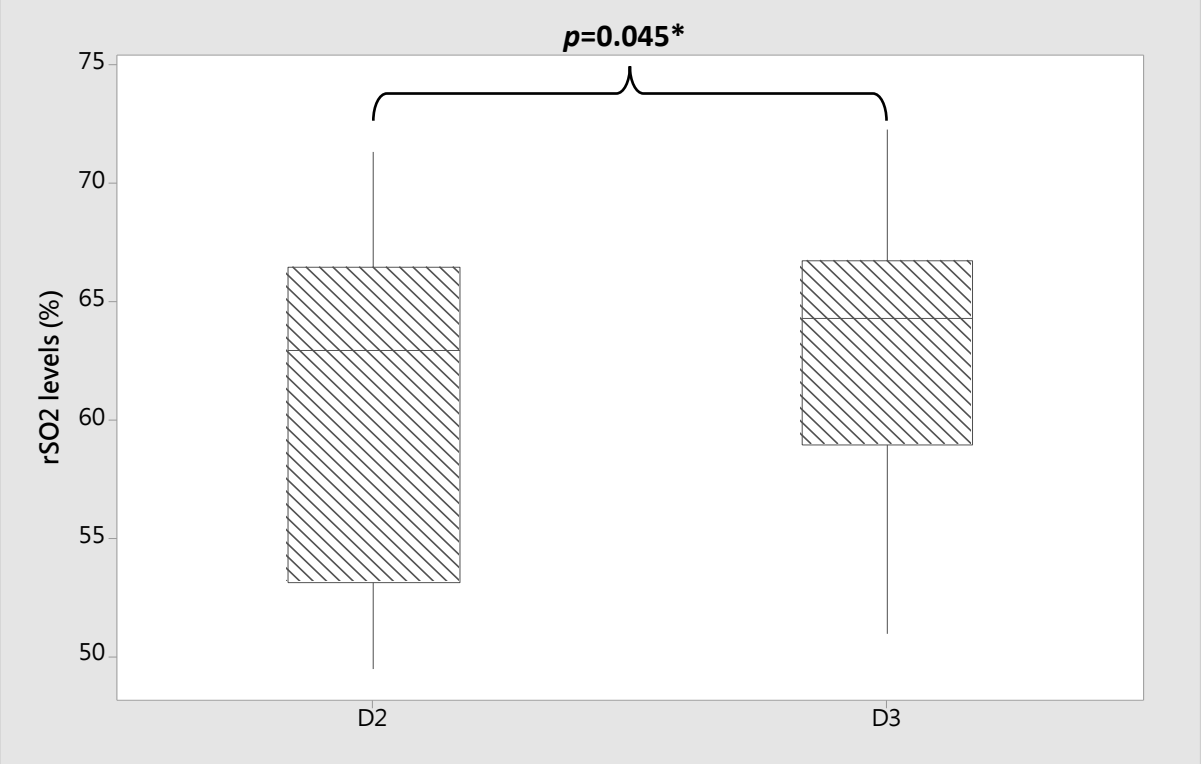

*Figure 24: Box plot of VL muscle oxygenation sitting baseline for D2 and D3 in the treatment leg. ♦ indicates an outlier. * indicates statistical significance between mean sitting baseline (indicated by horizontal line within bar) for D2 and D3*

The effect of duration of KT application shows that after 24 hours of KT application, 6 of 14 subjects (43%) VL sitting baseline increased only on the treatment leg. After wearing KT for 48 hours, 10 of the subjects (71%) increase/did not increase their sitting baseline levels in both legs at the same time. After 72 hours KT application, 5 subjects (36%) increased only on the treatment leg, and 4 subjects (29%) only increase in the control leg. RR results show that all the values are greater than 1, which means that KT application has positive association with VL increasing sitting baseline levels (Figure 25). However, the RR consistently decreases from 24 hours to 72 hours (24 hours RR=1.8, 48 hours RR=1.286, 72 hours RR=1.14) showing that the duration of KT application reduces this association between KT and VL sitting baseline. The duration of KT application results (Figure 26) show no statically significance increase after 24 (p=0.622), 48 (p=0.724), and 72 hours

(p=0.600) KT application.

Table 17: Number of subjects in each category of VL muscle oxygenation sitting baseline changes for each 24 hours period of KT application through D6 (72 hours after KT application)

Changes in VL muscle sitting baseline from D3	Number of Subjects		
	D4-D3	D5-D3	D6-D3
Increased in both legs	3	6	3
Not increased in both legs	3	4	2
Treatment leg increased	6	3	5
Control leg increased	2	1	4
Total subjects	**14**	**14**	**14**

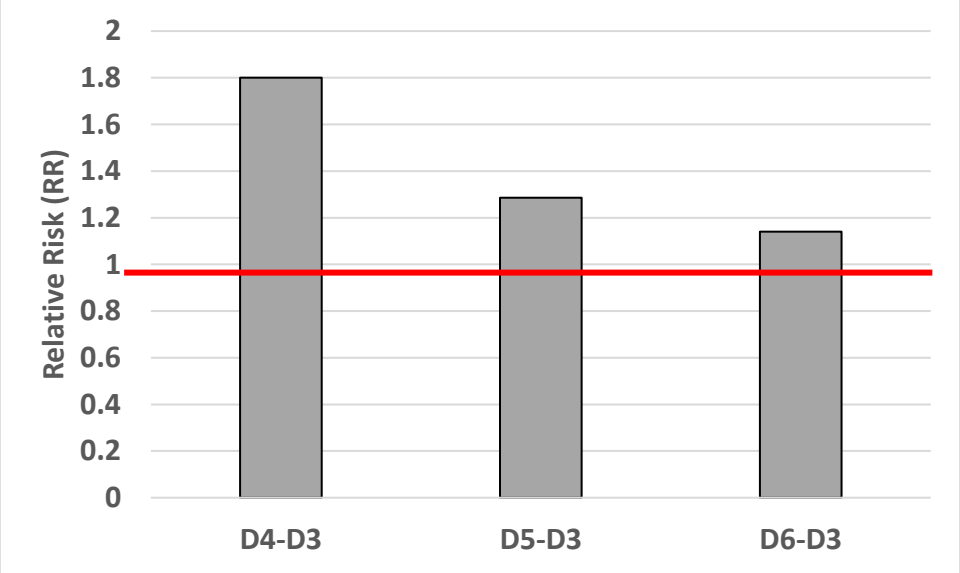

Figure 25: Relative risk for legs and changes in TTF based on the duration of KT application

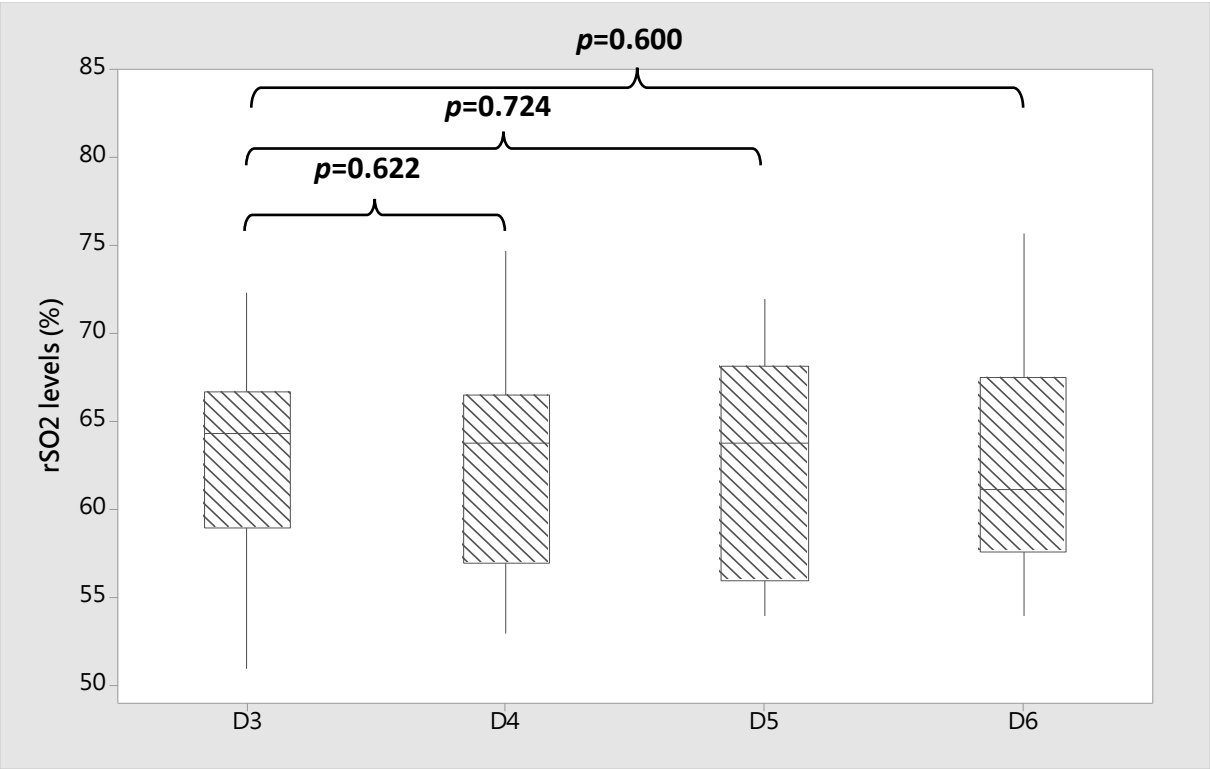

*Figure 26: Box plot of VL muscle oxygenation sitting baseline for D3, D4, D5, D6. ♦ indicates an outlier. * indicates statistical significance between mean muscle oxygenation sitting baseline (indicated by horizontal line within bar) for D3 to D4, D5, D6*

D7 compare to D6 and D2 can define the residual effect of KT application. According to D7 compared to D6, 10 of 13 subjects (77%) had both of their legs either increase or did not increase their VL sitting baseline level (Table 18). Only 1 of the subjects shows a residual effect, with the treatment leg increasing VL sitting baseline level from D6. When D7 is compare to D2, half of the subjects simultaneously increased or did not increased their sitting VL baseline rSO_2 levels for both legs. 4 of the subjects (31%) had a residual effect from KT application because only the treatment leg increased on D7. There were no statistically significant changes between D7 and D2 as well as between D7 and D6 for VL sitting baseline rSO_2 levels (p= 0.311; p=0.184) (Figure 27).

Table 18: Number of subjects in each category of VL muscle oxygenation sitting baseline changes based on the residual of KT application results. D7 (the day after 24 hours KT removed) compare to D6 (The last day of test with KT application), D2 (A day before KT application wearing)

Changes in VL muscle sitting baseline from D7	Number of subjects	
	D7-D6	D7-D2
Increased in both legs	5	4
Not increased in both legs	5	2
Treatment leg increased	1	4
Control leg increased	2	2
Total subjects	**13**	**12**

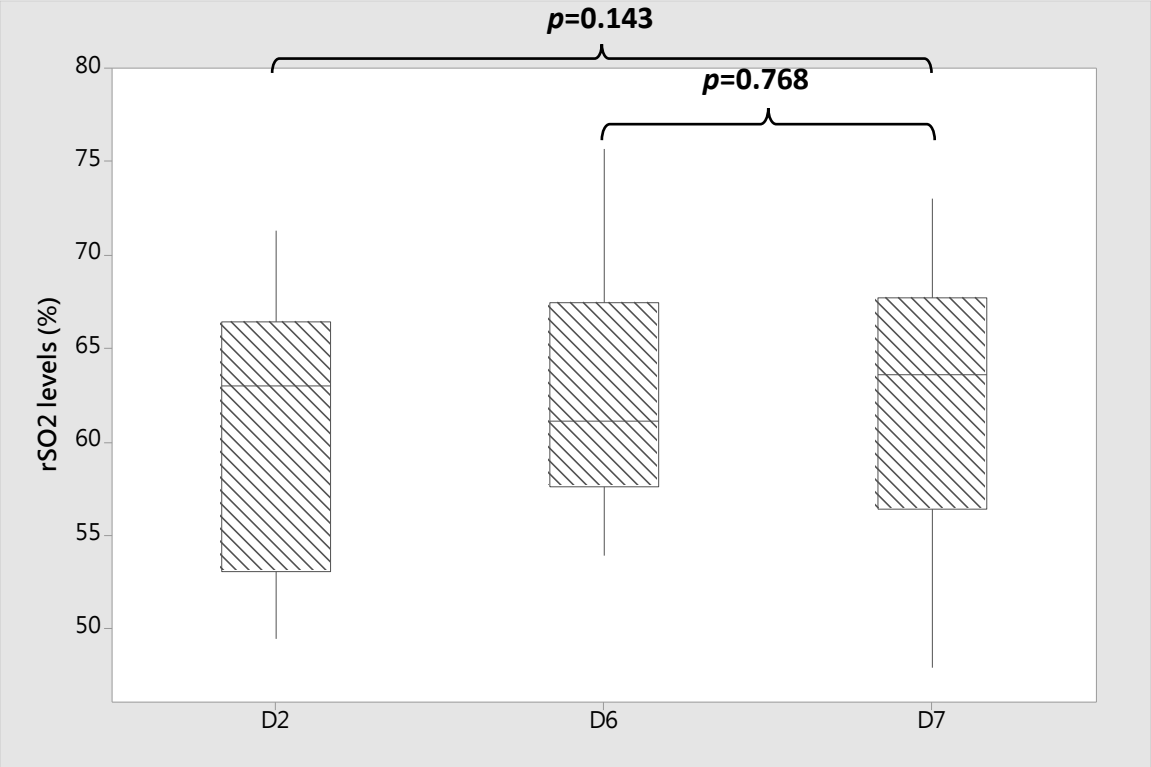

*Figure 27: Box plot of treatment leg VM muscle oxygenation sitting baseline for D2, D6, and D7. ♦ indicates an outlier. * indicates statistical significance between mean VM muscle oxygenation sitting baseline (indicated by horizontal line within bar) for D7 compare to D6 and D2 in treatment leg VM muscles*

3.2.2 Minimum rSO_2 level:

Vastus Medialis (VM): The results for acute KT application shows that 4 subjects (31%) had changes in minimum rSO_2 levels between D3 and D2 in different directions for both of their legs. 9 of 13 subjects (69%) had VM minimum rSO_2 levels increased/decreased in both legs (Table 19). The paired t-test results show that the

subjects experienced a statistically significant change in the VM minimum rSO_2 levels immediately after putting on the KT (p=0.022) (Figure 28).

Table 19: Number of subjects in each category of VM minimum rSO_2 levels changes based on acute KT application

Changes in VM minimum rSO_2 levels between D3 and D2	Number of subjects
Increased in both legs	6
Decreased in both legs	3
Treatment leg increased	3
Control leg increased	1
Total subjects	**13**

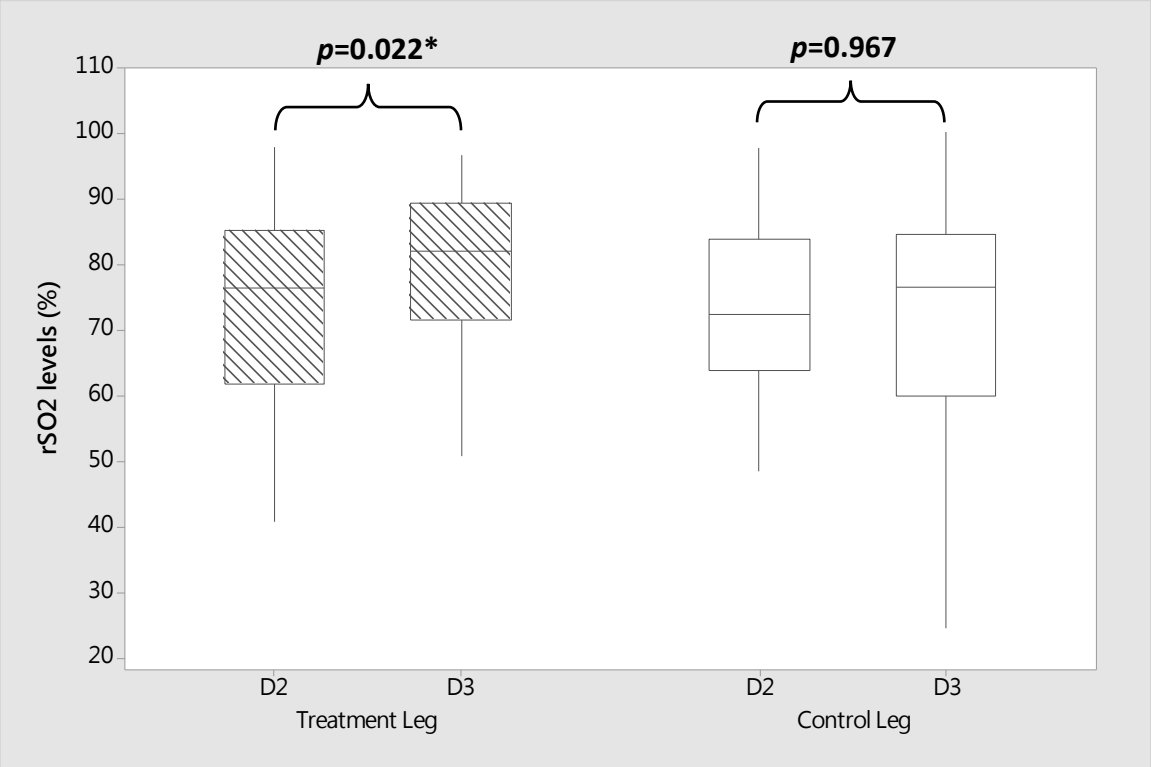

*Figure 28: Box plot of VM muscles of minimum rSO_2 levels on D2 and D3 for both the treatment and control leg. ♦ indicates an outlier. * indicates statistical significance between mean minimum rSO2 levels (indicated by horizontal line within bar) for D2 and D3.*

After 24 hours KT application, 7 subjects (54%) showed that the treatment and control leg either increase or decrease in opposite directions for their VM minimum rSO_2 levels, and 2 of the subjects had increases for the treatment leg, and the other 3 subjects show that KT will decreased the VM minimum rSO_2 levels for the treatment leg. After 48 hours 7 of 14 subjects (50%) show that minimum rSO_2

increases for one leg and decreases for their other leg. 5 of those subjects had an increase in minimum rSO_2 levels for the treatment leg. After 72 hours of wearing KT, 10 subjects (71%) had their control and treatment leg minimum rSO_2 levels change in different directions when compared to D3 (Table 20). The paired t-test results demonstrate that the duration of KT application will not change the effect of KT on minimum rSO_2, 24 (p=0.384), 48 (p=0.241), 72 hours (p=0.741) (Figure 29).

Table 20: Number of subjects in each category of VM minimum rSO_2 changes for each 24 hours period of KT application through D6 (72 hours after KT application)

Changes in VM minimum rSO_2 levels from D3	**Number of subjects**		
	D4-D3	**D5-D3**	**D6-D3**
Increased in both legs	3	2	2
Decreased in both legs	4	5	2
Treatment leg increased	2	5	4
Control leg increased	3	2	5
No change	1*	0	1**
Total subjects	**13**	**14**	**14**

* control leg VM minimum rSO_2 levels no change, treatment leg VM minimum rSO_2 levels increased
** control leg VM minimum rSO_2 levels decreased, treatment leg VM minimum rSO_2 levels no change

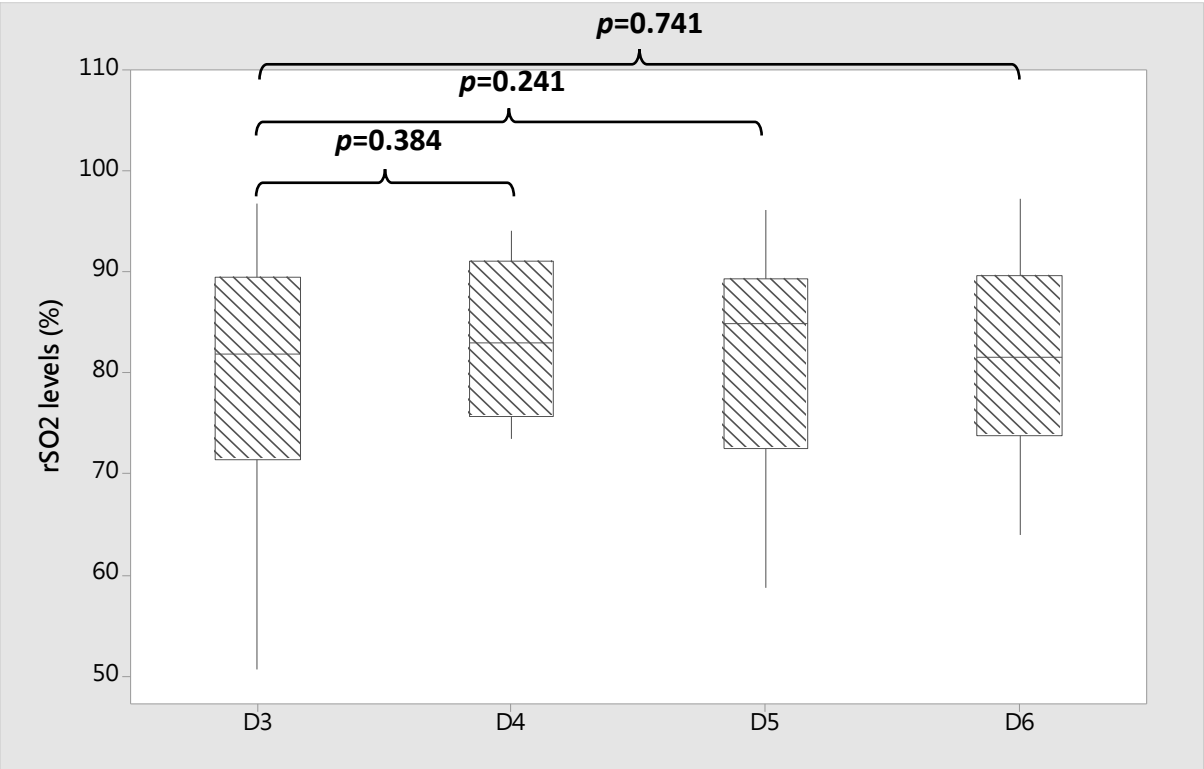

*Figure 29: Box plot of VM minimum rSO_2 levels in the treatment leg for D3, D4, D5, and D6. ♦ indicates an outlier. * indicates statistical significance between mean minimum rSO2 levels (indicated by horizontal line within bar) for D3 to D4, D5, D6*

The residual effect was checked by D7 compare to D2 and D6. In the raw data grouping result, none of subject has no change between days. 7 of the subjects (54%) might experience the KT residual effect 24 hours after removal. When comparing D7 to D2, 5 subjects (42%) have residual possible effect (Table 21). Nevertheless, the paired t-test results show that the minimum rSO_2 have insignificant differences between D7 and D2 (p=0.215). The D7 and D6 comparison also presents that insignificant change was discovered between the two days (p=0.314) (Figure 30). The results all indicate that KT will not have residual effect in minimum rSO_2 levels 24 hours after removal.

Table 21: Number of subjects' in each category of VM minimum rSO_2 changes based on the residual of KT application results. D7 (the day after 24 hours KT removed) compare to D6 (The last day of test with KT application), D2 (A day before KT application wearing)

Changes in VM minimum rSO_2 levels from D7	**Number of Subjects**	
	D7-D6	**D7-D2**
Increased in both legs	2	4
Decreased in both legs	4	3
Treatment leg increased	2	2
Control leg increased	5	3
Total subjects	**13**	**12**

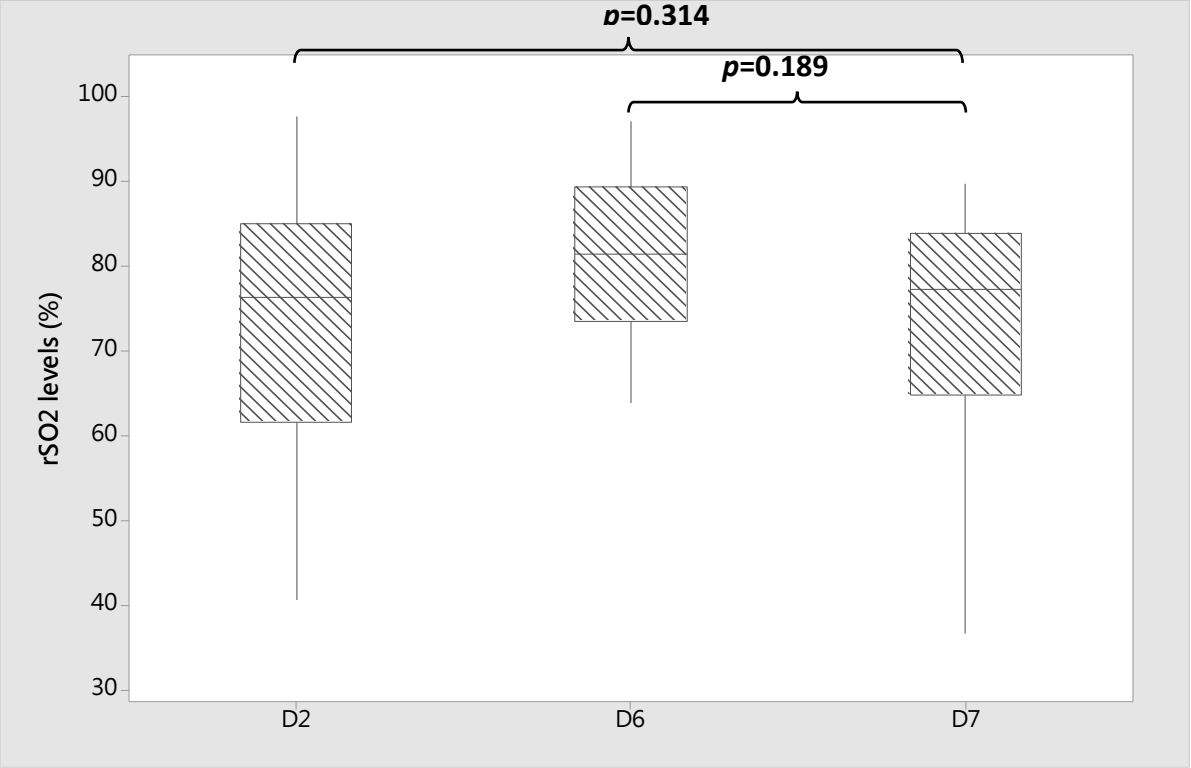

*Figure 30: Box plot of the treatment leg VM minimum rSO_2 levels on D2, D6, D7. ♦ indicates an outlier. * indicates statistical significance between mean VM minimum rSO2 levels (indicated by horizontal line within bar) for D7 compare to D6 and D2 in treatment leg VM muscles*

Vastus Lateralis (VL): The immediate KT application does not show a difference in raw data grouping results, because 9 of the subjects (69%) increase/decrease the VL minimum rSO_2 in both legs (Table 22). The acute KT application does not show a significant difference (p=0.182) in the VL minimum rSO_2 levels (Figure 31).

Table 22: Number of subjects in each category of changes in VM minimum rSO_2 levels based on acute KT application

Changes in VL minimum rSO_2 levels between D3 and D2	Number of subjects
Increased in both legs	7
Decreased in both legs	2
Treatment leg increased	3
Control leg increased	1
Total	**13**

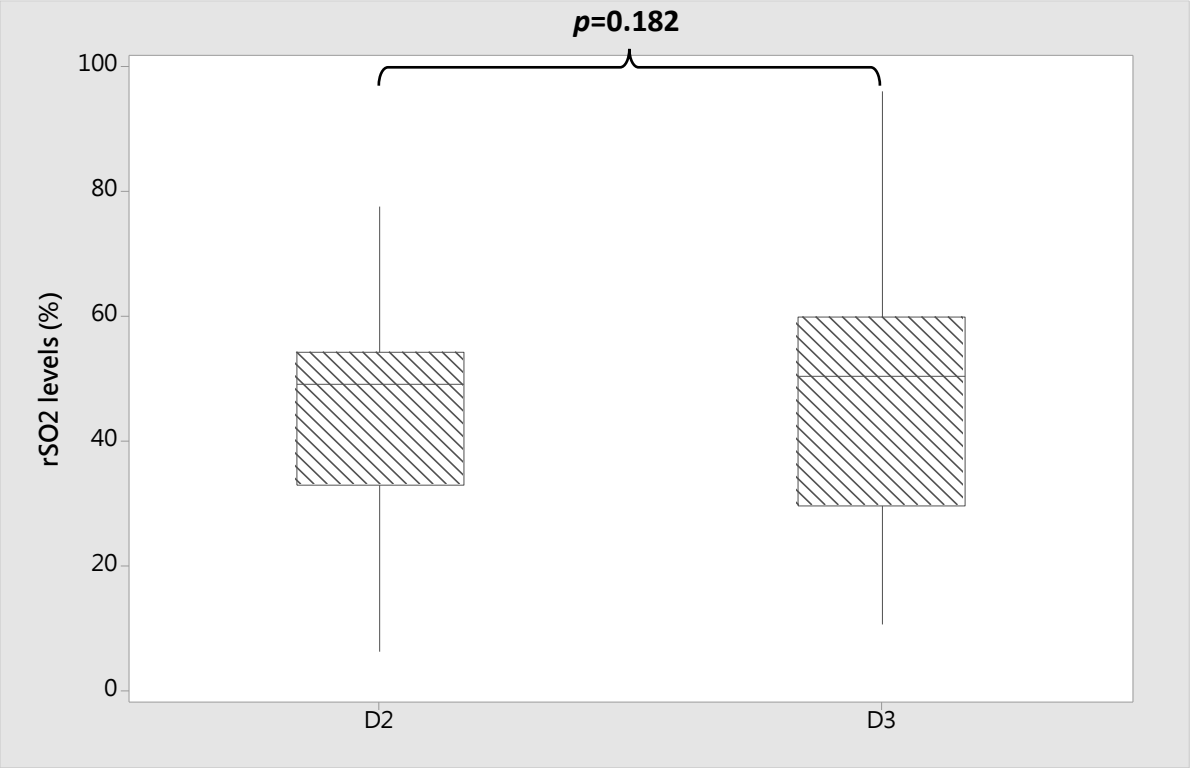

*Figure 31: Box plot of the treatment leg VL minimum rSO_2 levels for D2 and D3. ♦ indicates an outlier. * indicates statistical significance between mean minimum rSO2 levels (indicated by horizontal line within bar) for D2 and D3*

Secondly, the duration of KT application effectiveness were examined by D3 compared with D4 through D6. When D4 is compared to D3, 10 of the subjects (77%) increase/decrease VL minimum rSO_2 levels in both legs. After 48 hours KT application, 50% of subjects' treatment leg VL minimum rSO_2 changed differently from the control leg. When D6 is compared to D3, 10 subjects (71%) had the minimum rSO_2 levels increase/decrease in both legs (Table 23). According to the

raw data grouping, the duration effect of KT application cannot be explained. Furthermore, the paired t-test results show that no significant difference was discovered in 24 (p=0.297), 48 (p=0.379), or 72 hours (p=0.321) after KT application (Figure 32).

Table 23: Number of subjects in each category of changes in VL minimum rSO_2 levels for each 24 hours period of KT application through D6 (72 hours after KT application)

Changes in VL minimum rSO_2 levels from D3	Number of subjects		
	D4-D3	D5-D3	D6-D3
Increased in both legs	3	2	6
Decreased in both legs	7	5	4
Treatment leg increased	1	4	1
Control leg increased	2	3	3
Total	13	14	14

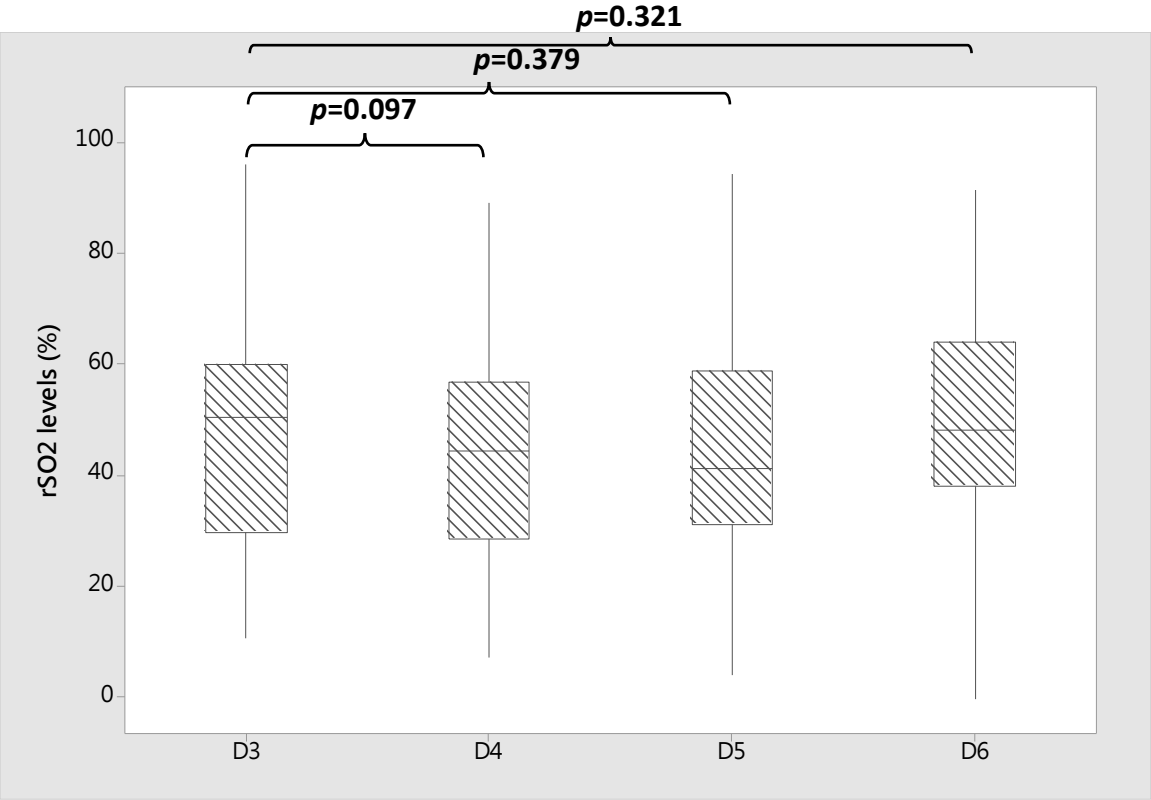

*Figure 32: Box plot of VL minimum rSO_2 levels in the treatment leg for D3, D4, D5, and D6. ♦ indicates an outlier. * indicates statistical significance between mean minimum rSO2 levels (indicated by horizontal line within bar) for D3 to D4, D5, D6*

D7 comparison could explain the KT residual effect. The raw data show that 7 subjects (54%) might have a residual effect since the two legs changed in different ways. Nevertheless, since the same numbers of subjects were found to have the treatment leg and control leg minimum rSO_2 value change in the same directions, the residual effect may not exist. The paired t-test between D7 and D2 shows that the two days values are statistically insignificantly different (p=0.820). The result for D7 compared to D6 also shows that VL minimum rSO_2 levels have insignificant differences (p=0.125).

Table 24: Number of subjects in each category of changes in VL minimum rSO_2 levels based on the residual of KT application results. D7 (the day after 24 hours KT removed) compare to D6 (The last day of test with KT application), D2 (A day before KT application wearing)

Changes in VM minimum rSO_2 levels from D7	**Number of Subjects**	
	D7-D6	**D7-D2**
Increased in both legs	2	3
Decreased in both legs	4	2
Treatment leg increased	1	1
Control leg increased	5	6
No change	1*	0
Total subjects	**13**	**12**

*control leg minimum rSO_2 levels no change, treatment leg minimum rSO_2 levels decreased

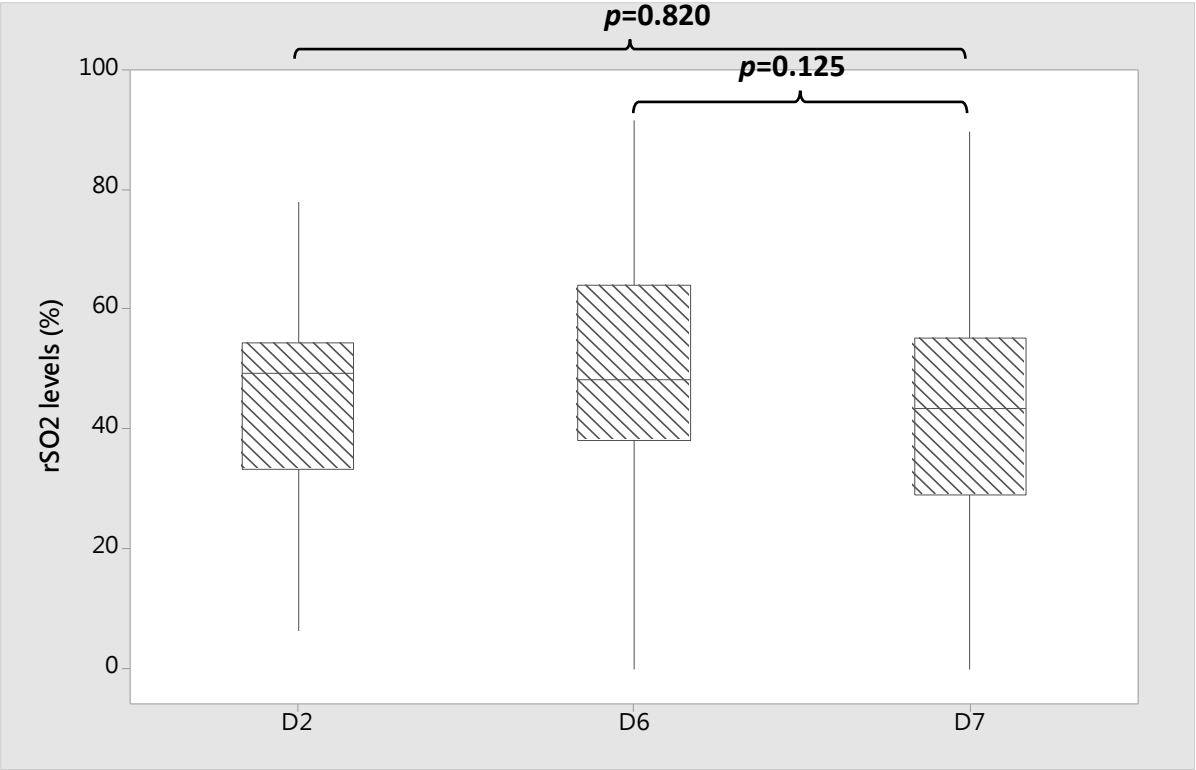

*Figure 33: Box plot of treatment leg VL minimum rSO_2 levels for D2, D6, and D7. ♦ indicates an outlier. * indicates statistical significance between mean VL minimum rSO2 levels (indicated by horizontal line within bar) for D7 compare to D6 and D2 in treatment leg VL muscles*

An example of muscle oxygenation over a trial is shown in Figure 34 for the treatment leg of subject 5 on D3. The rSO_2 level for the VL muscle drops rapidly at the beginning of the trial and then starts to recover. The VM muscle minimum rSO_2 levels are greater than the VL, which presents a comparative analysis for the minimum drop in rSO_2 levels for both muscle (VL and VM) in the taped and control legs respectively. VL rSO_2 levels always drop more than in the VM.

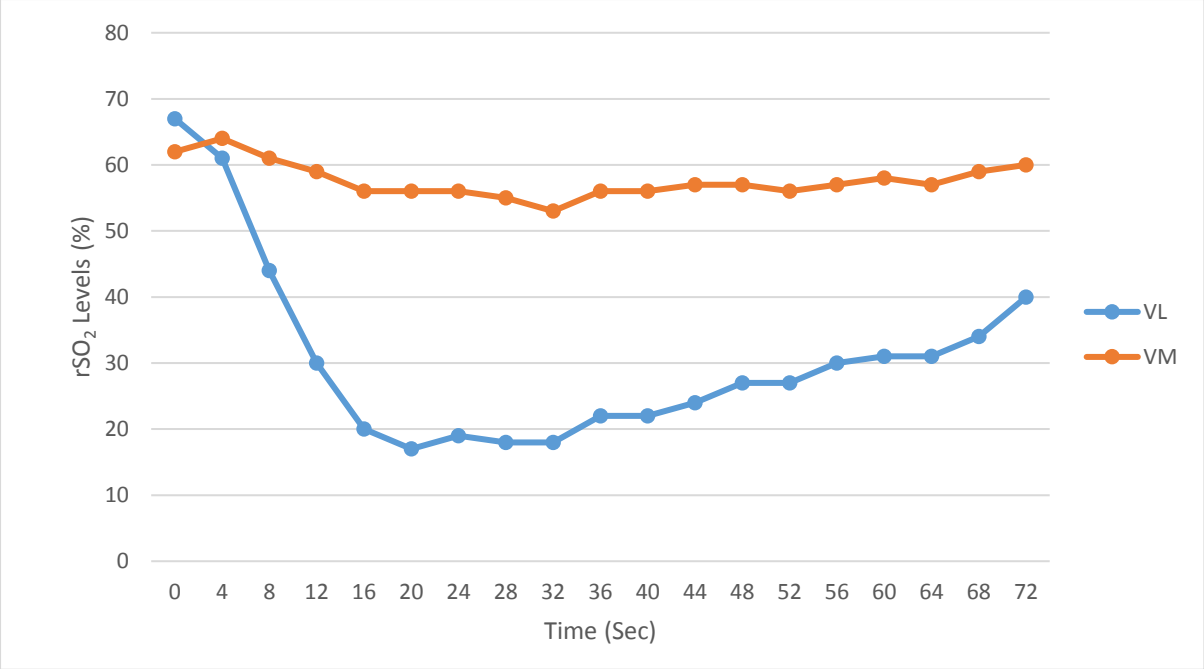

Figure 34: Example of muscle oxygenation trial (Subject 5, treatment leg, on D3)

3.2.3 Time to minimum rSO_2 level:

Vastus Medialis (VM): The acute KT application might influence the treatment leg VM time to minimum rSO_2, because 8 of 13 subjects (62%) show that the treatment leg changes differently from the control leg. Except for 1 subject who had no change in the treatment leg, 4 of the subjects have positive/negative changes simultaneously on both legs, and 4 of the subjects had an increase in the treatment leg, but a decrease in the control leg; and another 4 subjects decreased in the treatment leg, but had an increase in the control leg (Table 25). The treatment leg paired t-test result has no statistically significant difference to explain that the acute KT application will change the time to minimum rSO_2 (p=0.609) (Figure 35).

Table 25: Number of subjects in each category of changes in VM time to minimum rSO_2 based on acute KT application

Changes in VM time to minimum rSO_2 levels between D3 and D2	Number of Subjects
Increased in both legs	3
Decreased in both legs	1
Treatment leg increased	4
Control leg increased	4
No change	1*
Total subjects	**13**

* control leg time to minimum rSO_2 levels decreased, treatment leg time to minimum rSO_2 levels no change

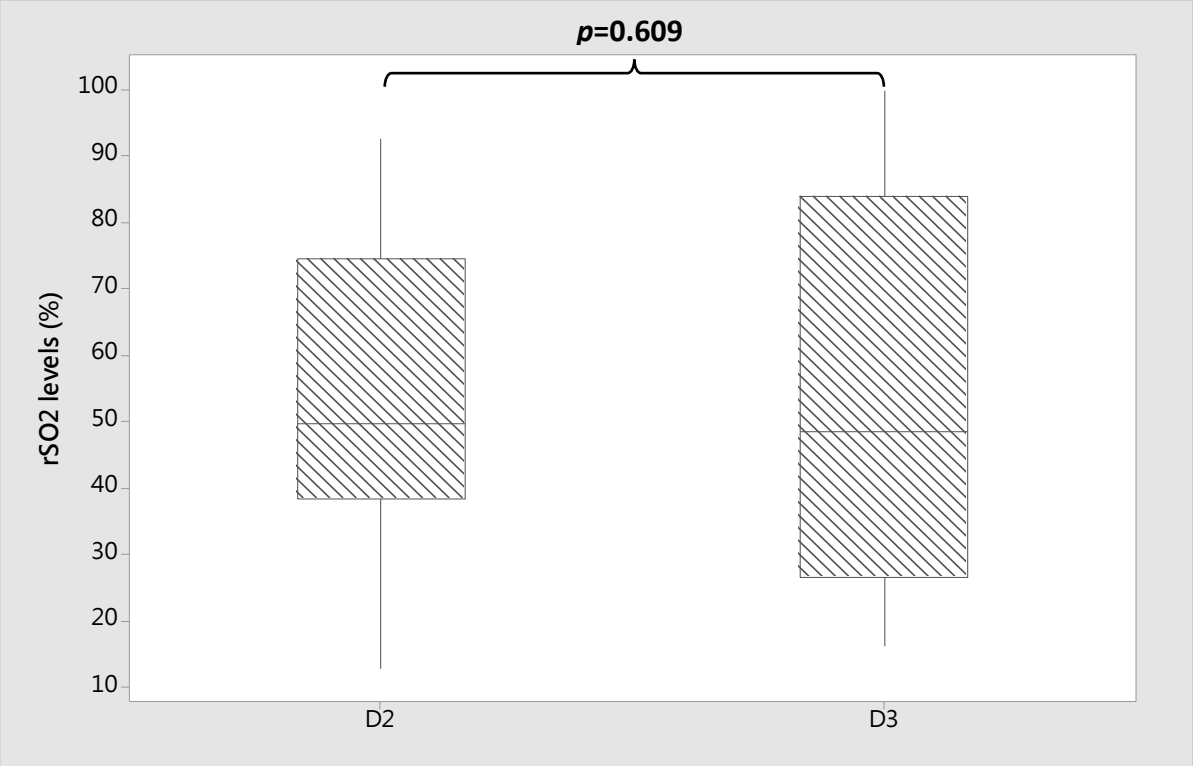

*Figure 35: Box plot of treatment leg VM time to minimum rSO_2 levels for D2 and D3. ♦ indicates an outlier. * indicates statistical significance between mean time to minimum rSO2 levels (indicated by horizontal line within bar) for D2 and D3*

Despite the acute KT application having no significant effect in VM time to minimum rSO_2 levels, the duration of KT application may still cause a change. Based on the raw data after 24 hours of KT application, 9 of the subjects (64%) increase/decrease simultaneously in both legs. 48 hours of KT application has 8 of

14 subjects (57%) both legs increase/decrease. And 72 hours of KT application shows 7 subjects (50%) time to minimum rSO_2 in the two legs increase/decrease together (Table 26). Furthermore, the duration of KT application comparison results show no statistically significant differences between acute KT application and other KT application days (24 hours p=0.613, 48 hours p=0.326, 72 hours p=0.253). After 48 hours of KT application, the time to minimum rSO_2 levels does occur earlier (mean difference =-0.062).

Table 26: Number of subjects in each category of changes in VM time to minimum rSO_2 levels for each 24 hours period of KT application through D6 (72 hours after KT application)

Changes in VM time to minimum rSO_2 levels from D3	**Number of subjects**		
	D4-D3	**D5-D3**	**D6-D3**
Increased in both legs	4	3	3
Decreased in both legs	5	5	4
Treatment leg increased	3	2	4
Control leg increased	1	4	1
No change	0	0	1* 1**
Total subjects	**13**	**14**	**14**

* control leg time to minimum rSO_2 levels decreased, treatment leg time to minimum rSO_2 levels no change
** control leg time to minimum rSO_2 levels increased, treatment leg time to minimum rSO_2 levels no change

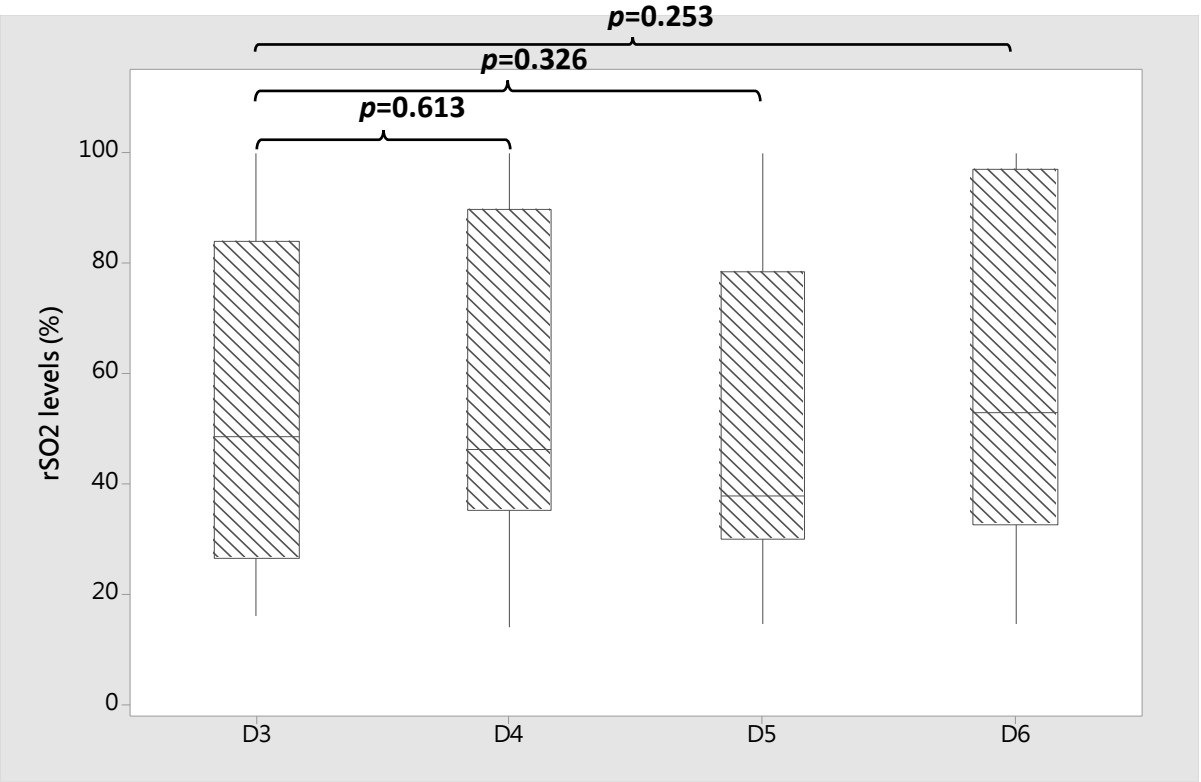

*Figure 36: Box plot of VM time to minimum rSO_2 for D3, D4, D5, and D6. ♦ indicates an outlier. * indicates statistical significance between mean VM time to minimum rSO2 levels (indicated by horizontal line within bar) for D3 to D4, D5, D6*

When D7 is compared to D6, the results explain the residual effect. Table 27 shows that only 3 subjects might have a residual effect, because all the other subjects (77%) increase/decrease in both legs (7 subjects) or have no change in the treatment leg (3 subjects). When the results from 24 hours after KT removal are compared to before KT application, 5 of 12 subjects (42%) VM time to minimum rSO_2 increase/decrease in both legs. 6 of 12 subjects (50%) increase/decrease oppositely between the two legs, but 5 subjects have time to minimum rSO_2 delayed in treatment leg and a shift to an earlier time in the control leg. The paired t-test results show that D2 (p=0.332) and D6 (p=0.826) both have no statically significant difference with D7 (Figure 37). Hence, the residual effect from KT doesn't exist.

Table 27: Number of subjects in each category of changes in VM time to minimum rSO_2 levels based on the residual of KT application results. D7 (the day after 24 hours KT removed) compare to D6 (The last day of test with KT application), D2 (A day before KT application wearing)

Changes in VM time to minimum rSO_2 levels from D7	**Number of subjects**	
	D7-D6	**D7-D2**
Increased in both legs	3	3
Decreased in both legs	4	2
Treatment leg increased	1	5
Control leg increased	2	1
No change	2* 1**	1*
Total subjects	**13**	**12**

* control leg time to minimum rSO2 levels decreased, treatment leg time to minimum rSO2 levels no change

** both legs time to minimum rSO2 levels no change

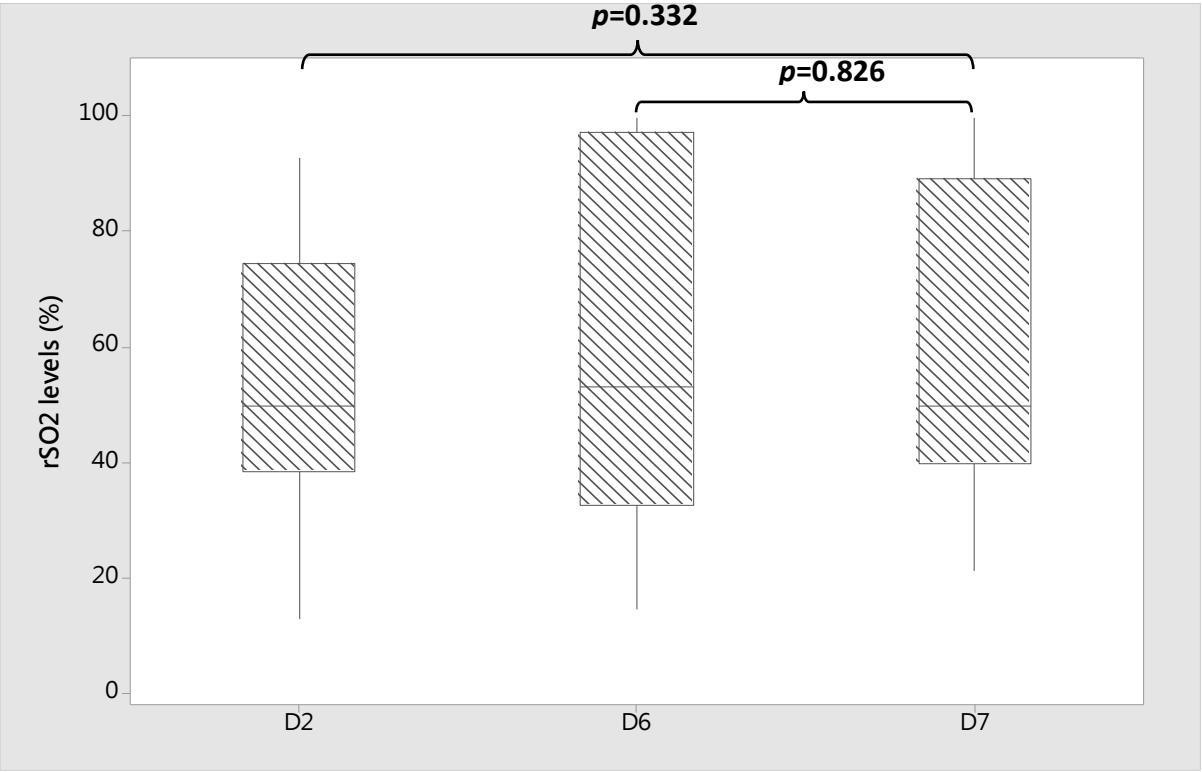

*Figure 37: Box plot of the treatment leg VM time to minimum rSO_2 levels for D2, D6, and D7. ♦ indicates an outlier. * indicates statistical significance between mean VM time to minimum rSO2 levels (indicated by horizontal line within bar) for D7 compare to D6 and D2 in treatment leg VM muscles*

Vastus Lateralis (VL): Table 28 shows that 8 of the subjects (62%) did not increase/decrease simultaneously in two legs after the acute KT application. Nevertheless, 4 of 8 subjects have time to minimum rSO_2 increased, and the others

are decreased. Therefore, two-sided paired t-test was chosen for analysis. The result shows no statistically significant difference between D2 and acute KT application (p=0.814).

Table 28: Number of subjects in each category of changes in VM time to minimum rSO_2 levels based on acute KT application

Changes in VL minimum rSO_2 levels between D3 and D2	**Number of subjects**
Increased in both legs	2
Decreased in both legs	3
Treatment leg increased	4
Control leg increased	4
Total subjects	**13**

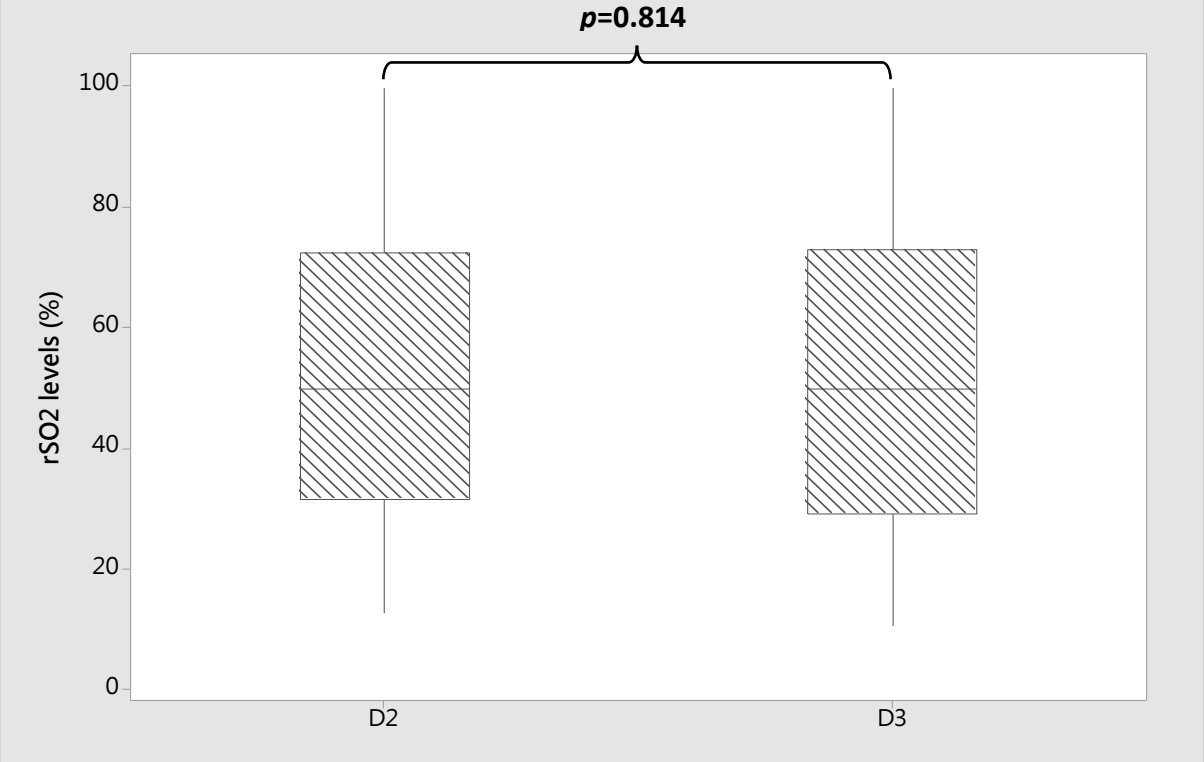

*Figure 38: Box plot of the treatment leg VL time to minimum rSO_2 levels for D2 and D3. ♦ indicates an outlier. * indicates statistical significance between mean time to minimum rSO2 levels (indicated by horizontal line within bar) for D2 and D3*

VM (Table 26) and VL (Table 29) have almost the same number of subjects in each group after 24 hours of KT application. Similarly, after 72 hours of KT

application, VM and VL have almost the same number of subjects in the same group as well. After 48 hours, for the VL muscle, 11 of 14 subjects (79%) indicate that KT will not change the time to minimum rSO_2 levels when compared to acute KT application and 48 hours of KT application. The duration of KT application results from 24 (p=0.063), 48 (p=0.367), and 72 hours (p=0.529) show that the subjects did not experienced a statistically significant difference in time to minimum rSO_2 levels after applying the KT.

Table 29: Number of subjects in each category of changes in VL time to minimum rSO_2 levels for each 24 hours period of KT application through D6 (72 hours after KT application)

Changes in VL time to minimum rSO_2 levels from D3	**Number of subjects**		
	D4-D3	**D5-D3**	**D6-D3**
Increased in both legs	4	6	4
Decreased in both legs	5	5	4
Treatment leg increased	2	2	4
Control leg increased	2	0	1
No change	0	1**	1**
Total subjects	**13**	**14**	**14**

* control leg time to minimum rSO_2 levels decreased, treatment leg time to minimum rSO_2 no change
** treatment leg time to minimum rSO_2 decreased, control leg time to minimum rSO_2 no change

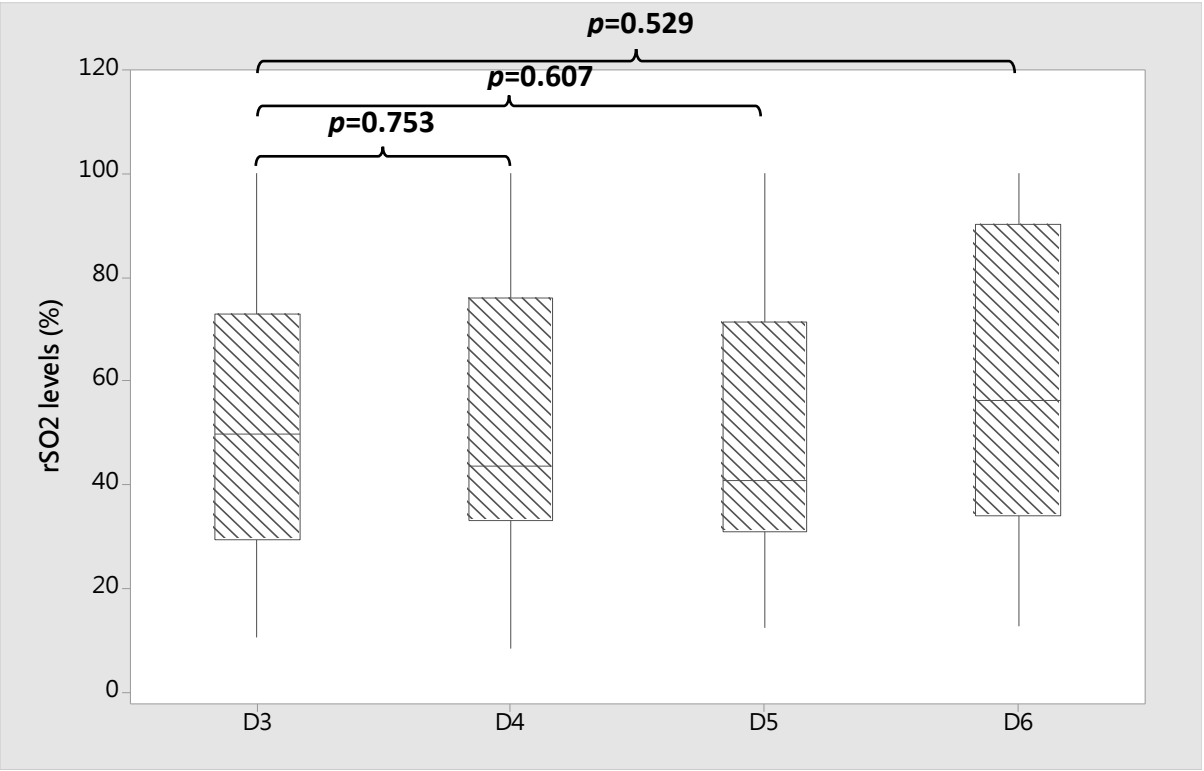

*Figure 39: Box plot of VL time to minimum rSO_2 levels for D3, D4, D5, and D6 in treatment leg. ♦ indicates an outlier. * indicates statistical significance between mean time to minimum rSO2 levels (indicated by horizontal line within bar) for D3 to D4, D5, D6*

After removing the KT for 24 hours, 8 subjects (62%) show that the treatment leg increases/decreases differently from the control leg, However, 4 of 8 subjects time to minimum rSO_2 increased, and the other 4 subjects decreased, which cannot demonstrate that KT has a residual effect in time to minimum rSO2 levels. When D7 is compared to D2, 67% of subjects' time to minimum rSO2 in both legs changed simultaneously (Table 30). Moreover, the paired t-test results (Figure 40) interpret that no significant difference were found when comparing D7 to before KT application (p=0.626) and after 72 hours of KT application (p=0.201). the residual effect from KT does not exist due to the D7 comparison to before KT application and after 72 hours of KT application results.

Table 30: Number of subjects' in each category of changes in VL time to minimum rSO_2 levels based on the residual of KT application results. D7 (the day after 24 hours KT removed) compare to D6 (The last day of test with KT application), D2 (A day before KT application wearing)

Changes in VM minimum rSO_2 levels from D7	Number of subjects	
	D7-D6	D7-D2
Increased in both legs	1	2
Decreased in both legs	4	6
Treatment leg increased	3	2
Control leg increased	3	1
No change	1* 1**	1***
Total	13	12

* treatment leg time to minimum rSO_2 levels decreased, control leg time to minimum rSO_2 levels no change

** treatment leg time to minimum rSO_2 levels increased, control leg time to minimum rSO_2 levels no change

*** control leg time to minimum rSO_2 levels decreased, treatment leg time to minimum rSO_2 levels no change

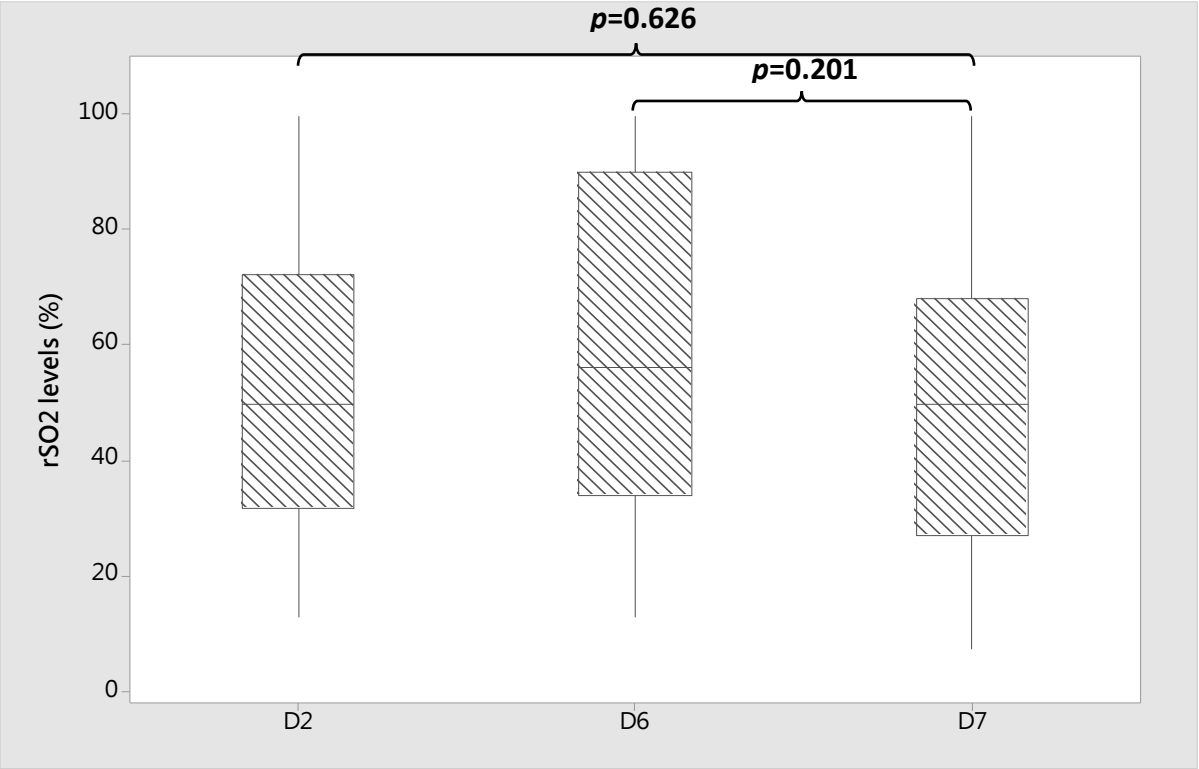

*Figure 40: Box plot of the treatment leg VL time to minimum rSO_2 levels for D2, D6, and D7♦ indicates an outlier. * indicates statistical significance between mean VL time to minimum rSO2 levels (indicated by horizontal line within bar) for D7 compare to D6 and D2 in treatment leg VL muscles*

Overall, the results demonstrate the changes and trends from D2 to D7. The TTF and rate results indicate that significant change is not due to KT, but from another factor. The muscle oxygenation results show that KT can change the rSO_2 level. The reason for this is that the rSO_2 level significantly changes only occurred on the treatment leg during days with KT application. The changes in muscle oxygenation in VL and VM have different influences from KT application. Even though the VM muscle has some significant changes from KT in the sitting baseline result, VL had larger changes. However, in the minimum rSO_2 level comparison, VM has significantly smaller rSO_2 levels during KT application (D2 to D3), but no obvious changes occur in the VL muscle. The implications of these results will be explored in the discussion chapter.

Chapter 4 Discussion

The aim of this research project was to assess Kinesio Tape application effectiveness on isotonic fatiguing knee flexion/extension exercise. The results revealed that the application of KT to the knee joint does not enhance the performance of the knee in terms of TTF, rate or muscle oxygenation level in healthy subjects. Nevertheless, during the eight days of testing some delays in TTF, enhancements in rate of flexion/extension, and change in muscle oxygenation were observed in both legs – the leg that KT was applied to for 4 days and the control leg.

4.1 Fatiguing of Isotonic Knee Flexion Extension Exercise

4.1.1 Time to Fatigue (TTF): As a part of this research study it was hypothesized that KT application would delay the TTF during knee the flexion/extension isotonic exercise. Based on the results of the study the hypothesis cannot be supported. The reason is that the OR of D3 compared to D2 is equal to 0.75. The fact that acute KT application will not increase the TTF was supported by the Wilcoxon signed ranking test, OR, and the raw data. Secondly, the lack of a KT application duration effect on increasing the TTF was supported by the RR from 24 hours KT application to 72 hours KT application and the statistic results. Furthermore, the raw data shows that during the KT application, there are always 64% to 86% of subjects whose results suggest that KT is not the main factor to enhance the TTF. Thirdly, the KT residual effect in TTF was not discovered in this study. Even though the treatment leg result on D7 compared to D6 and D2 both indicate that the TTF still increases after removal of KT, the control leg results provide evidence that the effect is not from KT residual. Overall, the results suggest that the TTF performance increase observed over time in the current study was the

results of effects other than the KT.

Unlike the findings of the Knapman et al. (2016) study that showed healthy subjects' enhancement of the maximal extension peak torque in isokinetic exercise on lumbar due to KT application, this case-control study findings cannot support that the enhancement of the performance of a knee flexion/extension isotonic exercise protocol can be attributed to KT. The comparison of the treatment leg to the control leg provides important evidence that, based on the current results, the improvements could be attributed to a "learning effect" from the exercise performance over multiple days, rather than KT application. Poon (2014), in a review of isokinetic performance papers, states that observed changes in performance could be a placebo effect. In the TTF data there were no subjects for which the treatment leg TTF increased without a corresponding increase in control leg TTF. Therefore, it appears that no placebo effect was found in the TTF data when looking at the raw data. Moreover, TTF for 5 of 13 subjects increased consistently for both legs every day, which indicates a learning effect may have existed (K. Jackson et al., 2016; J.T. Han et al., 2014; C. Fahs et al., 2015).

4.1.2 Rate of Flexion/Extension: The results concerning hypothesis 2 show that the rate changed over time, but there was no evidence that the increase in rate was caused by KT application. The enhancements due to acute KT application were shown in the treatment leg in D3 compared to D2 (p=0.027) and OR (1.8), but the Power shows only a 66.93% chance that an increase of rate is actually due to the acute KT application. Therefore, increasing the number of subjects is needed in a follow-up study. However, the leg comparison for D3 to D2 shows that the difference

in treatment leg was not significantly different from the control leg (p=0.11), which suggests that the increase in treatment leg was not due to the acute KT application. The duration of KT application was proven to have negative effect after 24, 48, and 72 hours by RR result, and the Wilcoxon signed raking test also provides that no significant increase showed from extending the duration of KT application. The residual effect did not exist in the rate results, although the result in D7 compare to D2 shows a statistically significant increase. However, the control leg comparison and D2 compared to other days both support that the two legs have similar rate results, and the rate in both legs show increases. The time series result support the statement that the rate increase is caused by learning effect, because the difference trends between two legs are statistically insignificant.

Time series theory provides additional learning effect evidence. According to the number of subjects whose TTF and rate increased by the day factor, it is possible that most of the subjects enhanced their performance by practicing. However, some of the subjects have a negative coefficient in the time series. This result suggests that the relationship between TTF and rate be investigated. All the negative coefficients (β) in TTF or rate have a positive coefficient (β) on the opposite side (Table A- 5, Table B- 5). As a result, TTF decreases are caused by increasing rate (frequency). In contrast, a negative rate coefficient corresponds to a positive coefficient in TTF. Nevertheless, learning effect was also defined by the case and control leg time series comparison, TTF and rate both show that the treatment leg's performance is similar to the control leg.

Subject 12 has a lower TTF time series coefficient, but has the highest rate time series' coefficient in both legs. The questionnaire provides evidence that the subject began to change his exercise strategy on D4, which is also a day after he

participated in high intensity sports. From D4 to D7, subject 12 TTF increased consistently. On the other hand, 3 of the subjects' control leg and 4 of the subjects' treatment leg have a negative coefficient (β) in the TTF time series result (Eq 6). However, when examining the rate time series, the TTF decrease could be explained by subjects increasing the rate after D2. None of the subjects had TTF and rate response with negative coefficients at the same time in the time series, which indicates that subjects learned to perform better in TTF or rate.

A previous study mentioned that English soccer players will have different muscle strength and flexibility on the dominant and non-dominant legs, which is because the training that soccer players undergo are more focused on the dominant leg (Rahnama, 2005). Overall, in this study, the TTF and rate results both indicate that learning effect is the main cause of performance enhancement. It is clear that for TTF and rate there is no significant change in performance due to KT application or after its removal, which goes against some of the KT manufacturers' claims about performance enhancement (Hypothesis 1 & Hypothesis 2). In another point of view, the treatment leg and control leg results also provide evidence to show that in fatiguing isotonic flexion/extension exercise, the two legs TTF and rate performance are similar. A prior project assessed a balance leg training that was able to decrease the asymmetry between two legs in young tennis players (I. Sannicandro, 2014). Another study assessed that runners have similar performance in stride length (K. Maćkała, 2010), ground contact time (P.W. Wong, 2008), unilateral squat strength, and weight bearing stance (K. McCuedy, 2005) in both legs. The study shows that subjects who are runners or basketball players will have leg symmetry due to balanced leg training, which could eliminate the concerns in this study that 50% of the subjects have running/biking/basketball exercise habits.

4.1.3 Grouping

When looking at the data broadly, the results show that a learning effect is present, but also that some subjects improve less after KT application, and some of the subjects have more random changes in performance. This section discusses the category and classifies method results.

First, none of the subjects' TTF and rate decrease at the same time in the time series analysis. Secondly, all the negative TTF coefficient values in the time series match with a positive coefficient in the rate time series results, and vice versa. Therefore, summarizing the result from the questionnaire, raw data, and time series analysis, subjects could be classified into three different groups (a) Learning, (b) Placebo (González-Iglesias, 2009; Poon, 2014), and (c) rate control. According to the TTF and rate result, 5 of the subjects can be classified as learning effect, because the raw data increases by days, and the time series coefficients (β) are positive in TTF and rate (Table 31). A second group of subjects are classified due to the questionnaire results which indicate that those subjects believe that KT enhanced their performance. However, when examining the performance data for these subjects, (1) only a few subjects enhanced their performance during KT application, which means the KT did not actually improve subject performance, and (2) some subjects' performances are randomly varied, or always increasing, even after removal of the KT (for instance: S7, S8) (Table 31). Therefore, Subject 7 and Subject 8 were classified in both the learning and placebo groups. The third group were categorized by checking the TTF and rate result at the same time. 5 of the subjects' performance changed randomly from D2 through D7. However, when the TTF decreased, an increasing rate was found in the result, and the endurance and rate are correlated. As a result, the performance is not only related to learning effect,

but also associated with the rate changing. Nevertheless, the control leg and treatment leg show no dramatic difference between one another, which also indicates that the TTF performance changed by subjects' body decreases or increases by the rate, not by KT.

Table 31: Subjects grouped by learning effect, placebo effect, and rate control effect

Learning	Placebo	Rate Control
S3	S1	S5
S4	S2	S6
S7	S7	S11
S8	S8	S12
S10	S9	S14
	S13	

4.2 Muscle Oxygenation

It was hypothesized that the use of KT would change the leg muscle sitting baseline rSO_2 level (Hypothesis 3), rSO_2 minimum levels (Hypothesis 4) and the time to minimum rSO_2 level (Hypothesis 5). The manufacturers claim that KT will increase the blood flow and muscle oxygenation. The results of this research evaluate the truth of those claims.

4.2.1 Sitting Baseline rSO_2 level:

The manufacturer explained and believed that the skin was stretched back by KT (KT, Rock tape website). Therefore, KT not only increases the blood flow but also indirectly increases the muscle oxygenation.

Similarly, the previous study which tested 63 uninjured subjects' forearms,

shows that the muscle oxygenation baseline will not significantly change by measuring at different times (Cole, 2011).

The results reject hypothesis 3a, the acute KT application did not increase the VL or VM sitting baseline. The paired t-test states that the VM difference between D3 and D2 is not large enough to show the statistical significance (p=0.062), even though the sitting baseline in VM raw data grouping shows that the treatment leg only has two situations, (a) sitting baseline increase (b) sitting baseline decrease with control leg as well, and OR is equal to 6. The control leg results in the VM muscle shows that D3 compared to D2 is a statistically insignificant increase (p=0.825, mean difference=-1.14), which also gives evidence that the sitting baseline might decrease if the treatment leg has no KT application. The follow-up study needs to increase the number of subjects to show the truth.

The effect of acute KT application in VL sitting baseline has an OR greater than 1 (OR=2.133) which indicates that the acute KT application is associated with VL sitting baseline increasing. Nevertheless, although the paired t-test shows that VL sitting baseline is statistically significantly increased (p=0.045) by the acute KT application, it could be a false positive because the Power shows only a 64.2% chance that the increase in TTF could be explained by acute KT application. Nevertheless, the control leg result can be examined to show if the trends in the two legs' sitting baseline are similar. The result in the control leg VM presents that no statistically significant increase was found in sitting baseline (p=0.198). The follow-up study needs to include more subjects to show if the increase is truly positive. As a result, both VM and VL show that the acute KT application could be associated with increasing sitting baseline, but more subjects are needed to support the statement.

Hypothesis 3b was rejected by the VM and VL results. According to the VM results, the sitting baseline in some of the subjects decreased more by extending the KT application duration. The VM sitting baseline RR and paired t-test results explained that a longer duration of KT application will decrease the sitting baseline. Two possible reasons could be made, (a) the KT has a decreasing effect in VM muscle sitting baseline, (b) KT had an effect in acute KT application, but the effectiveness decreased with the duration of KT application.

VL and VM have similar results, but the RR in VL is always greater than 1. However, when the KT application is extended, less association was seen between KT and sitting baseline increases. Moreover, the paired t-test results suggest that the duration of KT application is not a factor in increasing the VL sitting baseline.

The hypothesis 3c was rejected by the D7 comparisons. The residual effect can be defined in two ways, (a) the sitting baseline still increases after KT is removed, and (b) the sitting baseline on D7 is close to the value with KT application. In both VM and VL the results indicate that D7 did not statistically significantly increase in sitting baseline when compare to D6, which suggests that the residual effect (a) is invalid. When D7 is compared to D2, both VM and VL results indicate no statistically significant increase in sitting baseline after KT removal. As a result, the residual definition (b) is abandoned as well, and no residual effect in rSO_2 sitting baseline was suggested.

4.2.2 Minimum rSO_2 level:

The literature review in this study did not find any previous research that discussed the minimum rSO_2 variable. Moreover, no reference can be considered to show how the minimum rSO_2 levels change after using KT. Therefore, a two-sided

test was chosen to investigate the change of minimum rSO_2.

In the VM muscle, hypothesis 4a failed to reject, due to the minimum rSO_2 levels' statistically significant change after the acute KT application (p=0.022, Power=80.7%). Not only that, to prove that the effect from acute KT application is true, the control leg was tested as well. The control leg result on D3 compared to D2 shows the minimum rSO_2 in VM is statistically insignificantly different (p=0.969, mean difference=0.0006). The mean difference in the treatment leg is equal to 0.0663, which determines that the acute KT increases the minimum rSO_2 in the VM. Moreover, the raw data also suggests that more than 69% of subjects have increased the minimum rSO_2 levels in the treatment leg VM when comparing D3 to D2. The reason for minimum rSO_2 increasing could be attributed to the manufacturers claim that the blood flow and muscle oxygen will be increased by KT.

The VL muscle rejects hypothesis 3a because the difference between D3 and D2 is not large enough. According to the raw data, even though 10 subjects increased the minimum rSO_2 value on D3, the increase in the minimum rSO_2 levels cannot support that the difference truly exists.

Both VM and VL suggest that the duration of KT application will not affect the minimum rSO_2. The results reject hypothesis 4b, because 24, 48, and 72 hours of KT application have no statistically significant changes when compared to D3.

Hypothesis 4c was rejected because VM and VL have no evidence to support the definition (a) and (b) for residual effects. However, according to the raw data grouping, D7 to D6 in the VM shows that 9 subjects' treatment leg minimum rSO_2 levels decreased (69%). Yet, when D7 is compared to D2, 50% of subjects' treatment leg minimum rSO_2 increased, and rest of the subjects decreased. On the

other hand, VL minimum rSO_2 raw data also shows 9 subjects' treatment leg minimum rSO_2 decreased. 8 subjects decreased in D7 compare to the D2 result, and it is rational that D7 compared to D6 and D2 have similar results, because no statistically significant differences were found in the VL muscle.

4.2.3 Time to minimum rSO_2 in the trial:

Based on the literature review in this study, none of the studies discuss the time to minimum rSO_2 variable. Also, no trend was found in the raw data, and the two-sided paired t-test was chosen to examine the differences. The influence in time to minimum rSO_2 in the trial is not related to KT. The acute KT application did not change the VM and VL time to minimum rSO_2 result, based on the D3 to D2 comparison which has no statistically significant changes. Therefore, hypothesis 5a was rejected. Secondly, the results of the duration of KT application in time to minimum rSO_2 in the VM and VL muscles also show no statistically significant change, hence hypothesis 5b was rejected. The duration of KT application results tell that after a longer KT application, more subjects will have different changes. However, the treatment leg did not provide any evidence that KT will delay the time to minimum rSO_2 or shift to an earlier time. Just as for the other hypothesis results, the residual effect was not found after KT was removed for 24 hours.

The reason for no change in time to minimum muscle oxygenation could be due to the fact that the time is related to the subject's isotonic exercise performance, and every subject utilized the muscles to execute the task in a different way. First of all, according to the TTF results, both legs' TTF are enhanced, but the calculation of time to minimum rSO_2 level in the trial is based on TTF and the time that minimum rSO_2 occurred. Therefore, when time to minimum rSO_2 as a percentage of TTF is

similar but TTF increased, the minimum rSO_2 time is postponed actually. As a result, the muscle oxygenation uptake duration and recovery start point are related to the exercise duration, and not necessarily independent.

Overall, every subject consumes the rSO_2 in the VM and VL muscle differently. Surprisingly, some of the subjects consume the rSO_2 differently between the control leg and treatment leg. But according to the 14 subjects' muscle oxygenation results, 3 main categories can be defined as below:

1. Some subjects will see a recovery during the isotonic flexion/extension exercise when it reaches to the minimum rSO_2. The VL muscle in some of the subjects has more oxygen uptake than the VM muscle during the isotonic flexion/extension exercise, and it also recovers more from the minimum rSO_2 levels (Figure 34).
2. The VL and VM muscles in some of the subjects will have the same trend which consumes and recovers the rSO_2 simultaneously during the trial (Figure 41).
3. Some of subjects always decrease until the end of the trial (Figure 42), hence the minimum rSO_2 will occur at 100% of TTF.

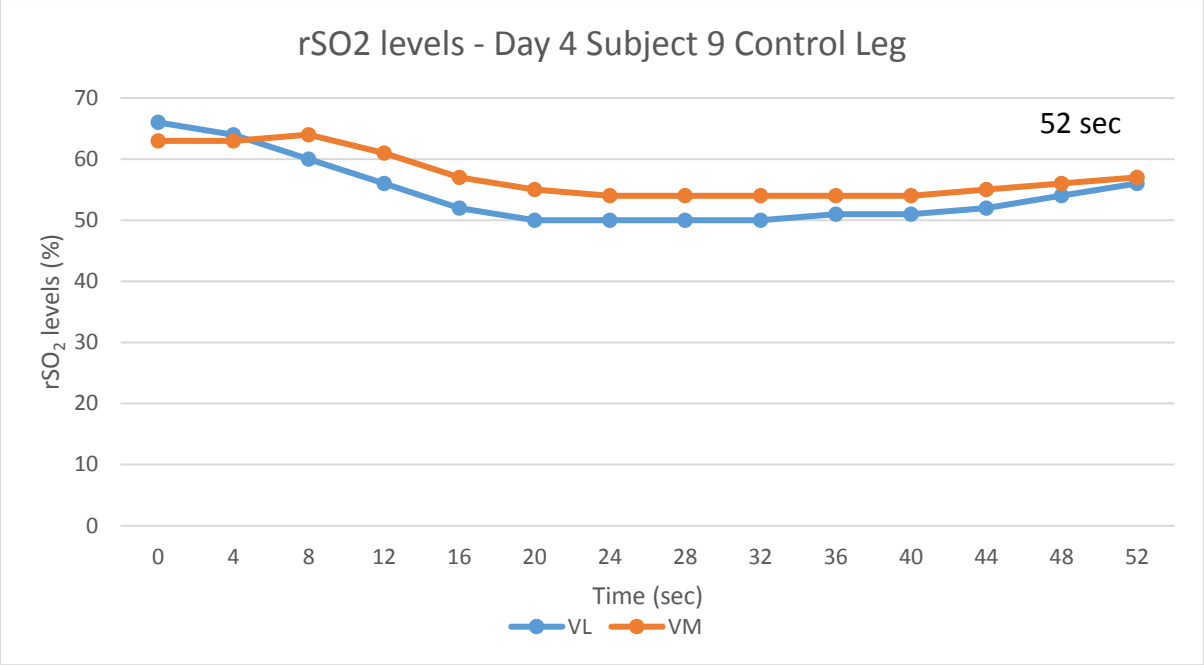

Figure 41: rSO_2 levels - D4 Subject 9 control Leg - an example of when VL and VM have similar rSO_2 consumption and trends. The time displayed in the graph is the respective end of that trial

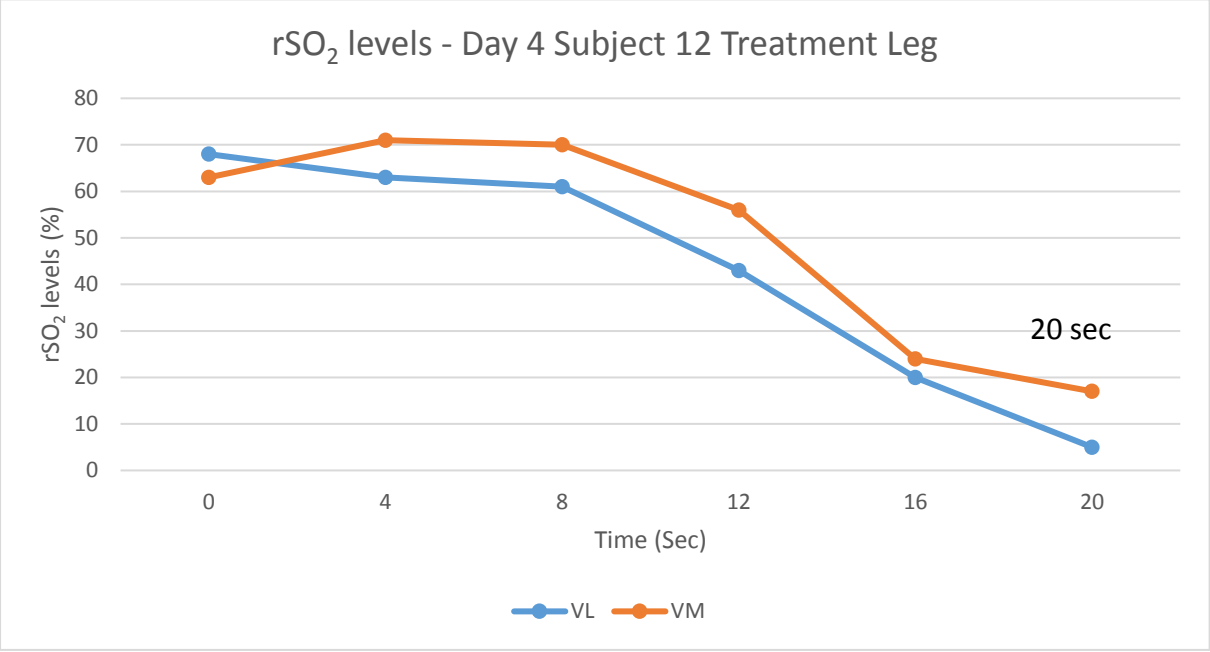

Figure 42: rSO_2 levels - D4 Subject 12 treatment Leg - An example of when VM and VL rSO_2 levels decrease until the end of the trial. The time displayed in the graph is the respective end of that trial

4.3 Summary

The goal of this research was to quantify the changes in performance and muscle oxygenation from acute and prolong KT application. Overall, there was

no evidence found to support that KT enhances isotonic knee flexion/extension endurance performance. The results of the subjects from acute and prolonged KT application were distributed from increasing, no change, and decreasing in TTF and rate. Subjects who were observed to have increased their performance also had indications of a learning effect or placebo effect.

There were changes due to KT application among the muscle oxygenation variables. The minimum level of rSO_2 during exercise did increase due to acute KT application. This could be due to the tape stretching the skin away from the muscle allowing oxygenated blood to flow more readily (which is claimed by the manufacturer), and thus the rSO_2 level did not reduce as much. Besides the increase observed in minimum rSO_2, KT did not result in any performance or muscle oxygenation changes.

4.4 Study Limitations

There are several limitations to this study that should be acknowledged. First, the duration of the test is eight days, which may not be long enough if evaluating the effect of KT on injury recovery. Future studies can have a longer project schedule to get more subjects enrolled.

Secondly, muscle strength could be included as a factor in future studies. There is substantial literature that uses electromyography to evaluate muscle strength and discuss the difference with/without Kinesiology Tape (Y. Konishi, 2013; Y. Shah, 2017; W. Moalla, 2006; C.Y. Huang, 2011; K. MacGregor, 2005; J. H. van Diee¨n, 2007). However, no study examined muscle strength (EMG data) with isotonic exercise. The performance changes from using KT might be more clearly defined if the relationship between muscle strength and exercise performance was

studied.

Third, the KT was always put on subjects' dominant leg in this research, which blocked the KT influences on the dominant and non-dominant leg. Future studies could add the leg factor to the experiment. Additionally, only one brand and one type of KT was used in this study, which limits the generalization of the results to all KT.

And last but not the least, the NIRS sensors are all put on the quads in this research. However, if the future study could overcome the comfort issue which is affected by the sensor placement, leg and Biodex, assessing the hamstring muscles is another viewpoint to discuss.

Chapter 5 Conclusion

This study was the first of its kind to determine the effects of KT application on healthy subjects during a fatiguing isotonic knee flexion/extension exercise. The reason for this study was to evaluate the claims of performance enhancement. Performance variables off TTF and rate were evaluated along with muscle oxygenation of the VL and VM muscles. The results in this study were:

- Application of KT to the knee joint did not enhance TTF and rate performance in isotonic flexion/extension exercise.
- KT application did increase the VL sitting baseline.
- Acute application of the KT increase the VM minimum rSO2 levels during exercise.
- Wearing KT increases the minimum rSO_2 levels during exercise.

This study did demonstrate that KT can cause changes in an individual muscle oxygenation levels through increasing their sitting baseline, and minimum level during exercise. Manufacturers make broad claims that KT can cause this changes, and this study supports this claim. However, manufacturers and athletes use this claim to support the notion that KT can also improve performance. No evidence was found in this study to support the notion of enhancing endurance performance during an isotonic knee flexion/extension exercise for this particular tape. Any increases could be due to a placebo effect or, also found in the current study, a learning effect. Further research should be completed in order to generalize these results across other tapes.

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APPENDICES

Appendix A: Isotonic Flexion/Extension Exercise TTF

Table A- 1: TTF during isotonic knee flexion/extension exercise from Day 2 to Day 8

	TTF (sec)													
	Day 2		Day 3		Day 4		Day 5		Day 6		Day 7		Day 8	
	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
S1	82	93	78	79	86	92	111	118	131	116	122	155	95	89
S2	39	39	40	39	36	41	48	46	45	49	45	49	51	62
S3	95.5	103	126	167	105.5	159	139	188	108	218	116.5	234.5	133	244
S4	114	181	135	217	107	270	144	182	191	211	209	316	258	255
S5	63	65	70	71	97	92	72	79	91	82	75	79	88	92
S6	160	70	93	94	75	70	81	91	92	123	N/A	N/A	N/A	N/A
S7	292	293	286	282	297	324	369	375	387	441	475	467	390	420
S8	46	45	49	51	58	56	60	59	64	65	67	66	75	72
S9	36	42	41	45	48	51	52	59	52	44	47	49	51	49
S10	23	25	11	26	28	21	32	31	28	17	30	30	30	23
S11	34	35	35	33	40	40	42	32	32	30	37	35	43	35
S12	47	50	37	48	25	19	19	20	24	23	21	23	22	27
S13	52	53	58	43	58	57	61	57	60	57	68	86	83	74
S14	60	69	53	67	52	47	45	48	38	38	38	50	46	51

Table A- 2: The distribution of changes in TTF for the treatment and control leg, which was used to calculate the OR based on the acute of KT application

		Treatment Leg	Control Leg
Exposure	Increase TTF	7	8
	No increase TTF	7	6
		OR	0.75

Table A- 3: Number of subjects with RR for TTF based on duration of KT application (D3 compare to D4 through D6)

	D4-D3		D5-D3		D6-D3	
	TTF Increased	TTF Not increased	TTF Increased	TTF Not increased	TTF Increased	TTF Not increased
Treatment Leg	9	5	9	5	8	6
Control Leg	7	7	11	3	9	5
	RR	1.286	RR	0.818	RR	0.89

Table A- 4: The statistic results for hypothesis 1 a (the acute KT application), 1b (duration of KT application), 1c (KT application residual effect).

Hypothesis	Days between	Mean difference	Range difference	*p-value*	Power
H1a. Acute of KT application	D3-D2	-2	20	*0.265*	33.6%
H1b. Duration of KT application	D4-D3	5.5	82	*0.235*	20.5%
	D5-D3	7.5	40	*0.063*	53.0%
	D6-D3	10	80	*0.139*	29.4%
H1c. KT application residual effect	D7-D2	12	162	*0.034**	99.6%▲
	D7-D6	8.5	42	*0.005**	92.5%▲
H1c. D7 compare to D2 and D6 control leg results	D7-D2	12	37	*0.005**	100.0%▲
	D7-D6	1	34	*0.380*	38.0%

* indicates statistical significance between median TTF for each hypothesis comparison
▲ presents the Power is greater than 80%

Table A- 5: The coefficient β in time series shows the TTF trends from D2 to D8 for each subject and each leg.

Subjects	Control Leg	Treatment Leg
S1	6.14	5.86
S2	1.964	3.464
S3	3.43	22.04
S4	23.71	12.89
S5	2.82	3.11
S6	-14.8	10.3
S7	27.21	31
S8	4.607	4.286
S9	2.179	0.79
S10	2.11	-0.07
S11	0.821	-0.214
S12	-3.86	-4.11
S13	4.107	5.32
S14	-3.071	-3.46
Mean Difference	2.42	
SD	8.94	
p-value	*0.165*	

* indicates statistical significance between control leg TTF for each hypothesis comparison.

Appendix B: Isotonic Flexion/Extension Exercise Rate

Table B- 1: Rate during isotonic knee flexion/extension exercise from Day 2 to Day 8

	Rate (cycle/sec)													
	Day 2		Day 3		Day 4		Day 5		Day 6		Day 7		Day 8	
	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
S1	0.476	0.505	0.551	0.544	0.500	0.533	0.495	0.517	0.519	0.517	0.541	0.529	0.579	0.663
S2	0.974	0.974	1.000	0.974	0.972	0.951	0.979	1.000	0.956	0.959	0.956	0.959	0.941	0.935
S3	0.775	0.835	0.651	0.856	0.853	0.890	0.820	0.872	0.833	0.856	0.850	0.896	0.812	0.881
S4	0.807	1.061	0.759	0.742	0.822	0.781	0.813	0.753	0.835	0.777	0.787	0.802	0.773	0.694
S5	0.857	0.792	0.807	0.845	0.825	0.772	0.826	0.810	0.835	0.817	0.840	0.861	0.847	0.793
S6	0.581	0.700	0.618	0.633	0.633	0.671	0.623	0.610	0.582	0.598	N/A	N/A	N/A	N/A
S7	0.808	0.812	0.839	0.819	0.862	0.840	0.846	0.891	0.881	0.862	0.851	0.925	0.892	0.886
S8	0.804	0.800	0.857	0.843	0.845	0.839	0.867	0.915	0.844	0.877	0.896	0.864	0.867	0.875
S9	0.833	0.762	0.780	0.733	0.833	0.745	0.788	0.695	0.769	0.818	0.894	0.816	0.941	0.939
S10	0.870	0.800	0.636	0.885	0.786	0.952	0.813	0.968	0.893	1.000	0.833	1.000	0.967	1.087
S11	0.941	0.800	0.943	0.879	0.925	0.875	0.905	0.938	1.125	0.967	0.919	0.914	0.907	0.914
S12	0.957	0.960	1.000	0.958	1.000	1.211	1.211	1.300	1.208	1.261	1.238	1.174	1.182	1.185
S13	0.865	0.981	0.828	1.047	0.879	0.965	0.902	0.982	0.867	0.947	0.912	0.884	0.843	0.892
S14	0.900	0.768	0.868	0.940	0.846	0.894	1.022	1.000	1.132	0.947	0.947	1.020	0.957	0.980

Table B- 2: The distribution of changes in rate for the treatment and control leg which was used to calculate the OR based on the acute of KT application

		Treatment Leg	Control Leg
Exposure	Increase	9	7
	Not increase	5	7
		OR	1.8

Table B- 3: Number of subjects with RR for rate based on duration of KT application (D3 compare to D4 through D6)

	D4-D3		D5-D3		D6-D3	
	Rate Increase	Rate Not increase	Rate Increase	Rate Not increase	Rate Increase	Rate Not increase
Treatment Leg	7	7	9	5	8	6
Control Leg	8	6	11	3	9	5
	RR	0.875	RR	0.818	RR	0.89

Table B- 4: The statistic results for hypothesis 2a (the acute KT application), 2b (duration of KT application), 2c (KT application residual effect).

Hypothesis in rate	Days between	Mean difference	Range difference	*p-value*	Power
H2a. Acute of KT application	D3-D2	0.039	0.239	*0.027**	66.9%
H2a. D3-D2 control leg results	D3-D2	0.034	0.091	*0.110*	37.5%
H2b. Duration of KT application	D4-D3	-0.004	0.149	*0.556*	7.3%
	D5-D3	0.021	0.406	*0.094*	39.2%
	D6-D3	0.007	0.215	*0.201*	22.9%
H2c. Residual after KT application	D7-D2	0.064	0.311	*0.015**	88.0%▲
	D7-D6	0	0.160	*0.447*	7.6%
H2c. D7 compare to D2 and D6 control leg results	D7-D2	0.044	0.127	*0.033**	63.4%
	D7-D6	0.016	0.184	*0.270*	24.5%

* indicates statistical significance between median rate for each hypothesis comparison
▲ presents the Power is greater than 80%

Table B- 5: The coefficient β in time series shows the rate trends from D2 to D8 for each subject and each leg.

Subjects	Control Leg	Treatment Leg
S1	0.011	0.015
S2	-0.007	-0.005
S3	0.018	0.007
S4	-0.001	-0.035
S5	0.002	0.003
S6	0.001	-0.023
S7	0.011	0.016
S8	0.009	0.011
S9	0.017	0.028
S10	0.028	0.041
S11	0.002	0.018
S12	0.049	0.041
S13	0.003	-0.022
S14	0.022	0.030
Mean Difference	-0.003	
SD	0.015	
p-value	*0.741*	

* indicates statistical significance between control leg Rate for each hypothesis comparison.

Appendix C: Sitting Baseline in VM/VL Muscles rSO_2 Levels Before the Test

Table C- 1: The sitting Baseline rSO_2 levels for the. (a) control leg VM muscles (b) control leg VL muscles (c) treatment leg VM muscles (d) treatment leg VL muscles

(a)

Raw data of sitting baseline % rSO_2 levels in control leg VM (%)								
VM	D1	D2	D3	D4	D5	D6	D7	D8
S1	58.00%	68.00%	65.33%	64.00%	69.00%	65.00%	67.00%	81.00%
S2	61.00%	51.33%	56.67%	57.33%	53.50%	59.00%	58.33%	55.33%
S3	77.00%	71.00%	66.00%	66.00%	68.00%	72.33%	68.00%	67.00%
S4	66.00%	70.00%	67.00%	65.50%	66.00%	64.00%	62.00%	69.67%
S5	47.00%	63.00%	58.67%	57.67%	61.00%	60.00%	64.00%	61.00%
S6	65.00%	64.00%	66.00%	54.00%	55.33%	60.33%	N/A	N/A
S7	63.00%	66.00%	62.33%	63.00%	63.33%	63.00%	63.33%	66.00%
S8	62.67%	61.50%	62.00%	60.33%	60.00%	55.00%	56.00%	57.00%
S9	51.33%	56.00%	60.00%	60.00%	54.67%	63.67%	57.00%	57.33%
S10	39.00%	35.00%	31.33%	44.00%	45.00%	36.67%	36.33%	21.33%
S11	60.00%	66.00%	65.00%	66.00%	67.00%	66.00%	61.00%	65.00%
S12	57.67%	56.50%	50.00%	60.00%	53.00%	50.67%	58.00%	52.00%
S13	59.67%	56.50%	62.00%	65.67%	66.33%	67.33%	59.50%	64.67%
S14	54.33%	58.67%	52.67%	56.67%	52.67%	64.00%	61.00%	61.00%

(b)

Raw data of sitting baseline % rSO_2 levels in VL control leg (%)								
	D1	D2	D3	D4	D5	D6	D7	D8
S1	64.00%	67.33%	67.00%	65.00%	63.50%	67.50%	70.00%	83.33%
S2	64.33%	55.33%	62.00%	62.00%	57.50%	59.67%	59.67%	61.33%
S3	73.50%	66.00%	65.00%	64.00%	68.67%	72.33%	69.00%	71.00%
S4	71.50%	71.00%	70.00%	70.00%	71.00%	70.67%	67.67%	71.67%
S5	44.00%	67.67%	62.00%	58.33%	57.33%	62.50%	64.00%	60.67%
S6	62.50%	63.00%	66.33%	63.50%	56.33%	63.33%	N/A	N/A
S7	70.33%	68.00%	70.67%	66.00%	69.33%	67.00%	68.00%	71.00%
S8	65.00%	61.00%	64.67%	63.33%	65.00%	59.33%	63.67%	59.00%
S9	57.00%	57.00%	63.67%	60.67%	57.00%	62.00%	56.00%	57.00%
S10	55.33%	52.00%	49.67%	58.00%	58.00%	51.00%	52.00%	48.00%
S11	65.67%	67.00%	67.00%	72.00%	68.75%	69.50%	62.67%	69.00%
S12	56.67%	54.00%	50.67%	57.00%	56.33%	50.67%	57.50%	45.00%
S13	65.33%	62.00%	67.00%	69.00%	69.67%	67.00%	66.50%	66.67%
S14	60.33%	63.33%	56.67%	57.67%	55.33%	64.00%	58.00%	65.00%

(c)

Raw data of sitting baseline % rSO_2 levels in VM treatment leg (%)								
VM	D1	D2	D3	D4	D5	D6	D7	D8
S1	59.00%	63.33%	61.00%	63.00%	56.67%	59.00%	63.50%	74.00%
S2	59.33%	50.50%	57.00%	59.00%	62.67%	61.00%	61.33%	60.50%
S3	78.00%	73.33%	80.00%	78.67%	69.00%	77.67%	70.00%	73.00%
S4	66.33%	64.00%	66.00%	61.00%	63.00%	72.00%	70.00%	68.00%
S5	53.67%	63.00%	63.67%	70.00%	73.00%	63.00%	64.33%	70.00%
S6	61.67%	62.50%	66.00%	62.00%	59.33%	65.33%	N/A	N/A
S7	61.00%	57.00%	64.00%	53.00%	62.00%	61.00%	65.00%	58.33%
S8	64.00%	63.00%	66.00%	66.33%	62.00%	61.00%	61.00%	68.00%
S9	50.67%	61.00%	63.33%	58.00%	56.00%	57.00%	59.00%	58.00%
S10	52.00%	45.33%	45.67%	46.00%	48.67%	47.33%	43.00%	50.00%
S11	57.67%	64.00%	64.00%	56.00%	57.00%	62.00%	57.67%	63.00%
S12	59.67%	59.33%	55.67%	61.00%	51.33%	56.00%	44.67%	47.67%
S13	60.00%	60.00%	73.00%	68.00%	79.50%	73.00%	58.33%	68.00%
S14	62.33%	N/A	62.33%	61.33%	59.25%	61.00%	61.00%	59.33%

(d)

Raw data of sitting baseline % rSO_2 levels in VL treatment leg (%)								
	D1	D2	D3	D4	D5	D6	D7	D8
S1	64.67%	67.00%	65.00%	65.50%	65.00%	60.33%	67.50%	81.50%
S2	55.67%	49.50%	51.67%	55.00%	59.33%	57.67%	58.00%	55.50%
S3	74.00%	71.33%	72.33%	74.67%	68.00%	75.67%	73.00%	69.67%
S4	70.33%	65.33%	66.00%	68.00%	69.00%	74.00%	69.67%	71.33%
S5	59.33%	53.00%	62.33%	63.00%	62.67%	57.50%	54.67%	61.00%
S6	58.33%	58.00%	61.00%	66.00%	56.00%	62.00%	N/A	N/A
S7	70.00%	63.00%	66.67%	58.67%	68.67%	67.00%	68.00%	63.33%
S8	66.33%	66.00%	66.00%	65.33%	67.00%	64.00%	65.50%	69.67%
S9	54.67%	57.00%	61.00%	57.67%	56.00%	59.00%	56.33%	59.33%
S10	55.67%	52.00%	51.00%	53.50%	55.00%	55.33%	56.67%	60.33%
S11	65.67%	69.00%	67.00%	70.00%	68.00%	67.00%	63.67%	67.00%
S12	56.33%	53.33%	53.00%	59.00%	54.00%	54.00%	48.00%	52.67%
S13	67.33%	64.00%	67.00%	64.67%	72.00%	69.00%	65.33%	68.00%
S14	61.00%	N/A	63.67%	53.00%	56.75%	58.00%	62.00%	62.00%

Table C- 2: The distribution of changes in muscle oxygenation sitting baseline for the treatment and control leg which was used to calculate the OR based on the acute of KT application. (a) VM muscles. (b) VL muscles

(a) VM muscles		Treatment Leg	Control Leg
Exposure Outcome	Increase	10	5
	Not increase	3	9
		OR	6

(b) VL muscles		Treatment Leg	Control Leg
Exposure Outcome	Increase	8	6
	Not increase	5	8
		OR	2.133

Table C- 3: Number of subjects with RR for muscle oxygenation sitting based on duration of KT application (D3 compare to D4 through D6). (a) VM muscles (b) VL muscles

(a) VM muscles	D4-D3		D5-D3		D6-D3	
	Increase	Not increase	Increase	Not increase	Increase	Not increase
Treatment Leg	6	8	3	11	4	10
Control Leg	7	7	9	5	10	4
	RR	0.857	RR	0.333	RR	0.4

(b) VL muscles	D4-D3		D5-D3		D6-D3	
	Increase	Not increase	Increase	Not increase	Increase	Not increase
Treatment Leg	9	5	9	5	8	6
Control Leg	5	9	7	7	7	7
	RR	1.8	RR	1.286	RR	1.14

Table C- 4: The statistic results for hypothesis 3a (the acute KT application), 3b (duration of KT application), 3c (KT application residual effect). (a) VM muscles. (b) VL muscles

(a) VM muscles

Hypothesis	Day between	Mean difference	S.D. difference	*p-value*	Power
H3a. Acute of KT application	D3-D2	2.55	4.75	*0.062*	60.2%
H3b. Duration of KT application	D4-D3	-1.94	5.32	*0.884*	36.3%
	D5-D3	-3.61	3.73	*0.993*	96.3%▲
	D6-D3	-0.97	3.56	*0.806*	24.9%
H3c. Residual after KT application	D7-D2	0.44	4.65	*0.399*	10.0%
	D7-D6	0.648	2.764	*0.251*	20.8%

* indicates statistical significance between mean muscle oxygenation sitting baseline for each hypothesis comparison
▲ presents the Power is greater than 80%

(b) VL muscles

Hypothesis	Day between	Mean difference	S.D. difference	*p-value*	Power
H3a. Acute of KT application	D3-D2	1.849	3.264	*0.045**	0.642
H3b. Duration of KT application	D4-D3	-0.46	4.98	*0.622*	0.094
	D5-D3	-0.66	3.72	*0.724*	0.155
	D6-D3	-0.29	3.88	*0.600*	0.084
H3c. Residual after KT application	D7-D2	1.32	4.07	*0.143*	0.311
	D7-D6	-0.78	3.72	*0.768*	0.184

* indicates statistical significance between mean muscle oxygenation sitting baseline for each hypothesis comparison
▲ presents the Power is greater than 80%

Appendix D: Minimum rSO_2 Levels in VM/VL Muscle During the Task

Table D- 1: The minimum rSO_2 levels in the trial for the (a) control leg VM muscles (b) control leg VL muscles (c) treatment leg VM muscles (d) treatment leg VL muscles

(a)

Minimum rSO_2 levels in treatment leg VM during the task (% change with sitting baseline)							
	D2	D3	D4	D5	D6	D7	D8
S1	52.38%	51.52%	31.75%	33.87%	38.81%	36.92%	35.90%
S2	60.78%	80.36%	88.33%	79.31%	80.95%	68.25%	57.89%
S3	81.58%	80.25%	78.67%	77.14%	79.49%	83.82%	78.95%
S4	62.69%	72.86%	83.05%	84.13%	82.35%	61.84%	67.69%
S5	73.33%	85.48%	85.71%	87.67%	90.77%	80.00%	76.39%
S6	88.89%	96.77%	90.57%	96.23%	95.08%	N/A	N/A
S7	70.49%	86.15%	83.05%	87.50%	77.05%	84.51%	89.23%
S8	81.36%	90.77%	92.54%	93.22%	86.21%	81.25%	89.23%
S9	76.47%	83.58%	79.03%	85.71%	85.71%	77.05%	81.67%
S10	97.92%	90.20%	94.12%	90.38%	97.30%	88.24%	93.88%
S11	89.06%	89.23%	93.10%	89.06%	89.23%	90.00%	89.06%
S12	40.91%	50.79%	26.98%	25.37%	33.90%	31.15%	27.59%
S13	77.59%	77.46%	73.53%	77.92%	78.57%	77.42%	76.47%
S14	N/A	67.61%	76.56%	58.82%	64.06%	75.00%	70.97%

(b)

Minimum rSO_2 levels in treatment leg VL during the task (% change with sitting baseline)							
	D2	D3	D4	D5	D6	D7	D8
S1	50.00%	51.52%	34.85%	38.81%	44.78%	39.06%	41.46%
S2	51.85%	41.38%	46.30%	40.74%	63.79%	50.85%	58.18%
S3	46.97%	56.25%	53.85%	58.44%	56.58%	43.48%	50.65%
S4	33.82%	36.59%	19.70%	32.84%	40.54%	39.51%	34.33%
S5	9.59%	25.37%	32.89%	27.14%	43.28%	25.68%	50.00%
S6	53.23%	59.70%	52.31%	56.45%	65.15%	N/A	N/A
S7	32.86%	31.43%	23.44%	35.71%	31.34%	55.07%	58.33%
S8	49.28%	64.18%	62.86%	55.07%	59.09%	46.97%	43.28%
S9	55.71%	59.72%	55.07%	60.34%	51.61%	55.74%	57.97%
S10	92.59%	96.30%	89.47%	94.44%	91.67%	89.83%	89.83%
S11	33.80%	50.00%	42.86%	42.31%	45.07%	32.31%	25.40%
S12	6.45%	12.90%	7.35%	4.35%	20.34%	0.00%	1.72%
S13	77.94%	61.76%	67.16%	70.83%	69.01%	67.61%	75.71%
S14	N/A	10.77%	30.36%	18.46%	0.00%	10.00%	37.93%

(c)

Minimum rSO_2 levels in control leg VM during the task (% change with sitting baseline)							
	D2	D3	D4	D5	D6	D7	D8
S1	50.00%	46.38%	52.17%	57.35%	52.17%	52.94%	51.25%
S2	62.00%	60.71%	56.14%	49.06%	68.52%	53.45%	39.13%
S3	84.93%	78.38%	85.07%	80.30%	85.48%	80.26%	81.33%
S4	64.29%	67.14%	N/A	55.22%	65.15%	65.57%	63.77%
S5	68.75%	69.70%	72.73%	70.59%	73.44%	79.03%	76.12%
S6	80.33%	83.33%	80.00%	82.54%	84.62%	N/A	N/A
S7	67.69%	74.63%	69.84%	75.36%	79.37%	73.53%	94.03%
S8	95.16%	93.75%	90.16%	88.52%	90.38%	87.93%	92.98%
S9	83.33%	88.52%	85.71%	87.27%	85.48%	86.67%	91.53%
S10	97.56%	100.00%	100.00%	97.83%	97.50%	97.67%	100.00%
S11	76.12%	80.88%	81.54%	75.36%	76.06%	80.33%	79.10%
S12	48.39%	24.56%	51.61%	21.74%	50.88%	41.38%	24.14%
S13	83.33%	82.46%	79.10%	77.61%	82.09%	79.31%	78.57%
S14	68.75%	57.14%	61.90%	53.23%	53.33%	64.06%	60.32%

(d)

Minimum rSO2 levels in control leg VL during the task (% change with sitting baseline)							
	D2	D3	D4	D5	D6	D7	D8
S1	13.85%	33.33%	50.70%	20.97%	40.30%	40.91%	38.75%
S2	61.02%	60.00%	70.97%	63.16%	72.13%	70.49%	57.14%
S3	59.15%	43.42%	42.42%	63.77%	48.57%	36.71%	53.16%
S4	28.95%	46.75%	N/A	41.03%	44.59%	38.24%	38.67%
S5	36.92%	21.13%	32.84%	28.36%	33.33%	40.58%	35.82%
S6	36.21%	46.03%	22.58%	31.75%	50.00%	N/A	N/A
S7	64.79%	72.97%	48.48%	57.33%	55.56%	64.29%	86.30%
S8	33.82%	52.17%	38.81%	57.58%	63.79%	62.50%	26.79%
S9	77.78%	79.37%	75.76%	75.00%	83.33%	84.21%	84.48%
S10	91.23%	98.11%	93.10%	91.38%	96.08%	96.23%	96.08%
S11	34.78%	44.29%	40.54%	32.47%	33.77%	44.44%	13.89%
S12	15.63%	3.57%	14.75%	8.62%	5.66%	25.00%	1.89%
S13	88.14%	81.82%	87.14%	80.28%	85.07%	85.07%	81.54%
S14	37.10%	37.50%	33.87%	28.57%	34.92%	0.00%	33.85%

Table D- 2: The statistic results for hypothesis 4a (the acute KT application), b (duration of KT application), c (KT application residual effect). (a) VM muscles. (b) VL muscles

(a) VM muscles

Hypothesis	Day between	Mean difference	S.D. difference	*p-value*	Power
H4a. Acute of KT application	D3-D2	0.066	0.081	*0.022**	80.7%▲
H4a. D3-D2 control leg results	D3-D2	0.001	0.051	*0.967*	5.4%
H4b. Duration of KT application	D4-D3	0.015	0.056	*0.384*	14.9%
	D5-D3	0.014	0.037	*0.241*	25.7%
	D6-D3	0.005	0.052	*0.741*	06.3%
H4c. Residual after KT application	D7-D2	0.021	0.063	*0.314*	21.5%
	D7-D6	-0.040	0.095	*0.189*	31.4%

* indicates statistical significance between mean minimum rSO_2 levels in the trial for each hypothesis comparison

▲ presents the Power is greater than 80%

(b) VL muscles

Hypothesis	Day between	Mean difference	S.D. difference	*p-value*	Power
H4a. Acute of KT application	D3-D2	0.041	0.100	*0.182*	42.6%
H4b. Duration of KT application	D4-D3	-0.028	0.097	*0.297*	17.2%
	D5-D3	-0.016	0.064	*0.379*	13.5%
	D6-D3	0.020	0.094	*0.321*	16.9%
H4c. Residual after KT application	D7-D2	0.007	0.103	*0.820*	5.7%
	D7-D6	-0.063	0.125	*0.125*	41.7%

* indicates statistical significance between mean minimum rSO_2 levels in the trial for each hypothesis comparison

▲ presents the Power is greater than 80%

Appendix E: Time to Minimum rSO_2 Levels During the Trial

Table E- 1: The minimum rSO_2 levels' in the trial for the (a) control leg VM muscles (b) control leg VL muscles (c) treatment leg VM muscles (d) treatment leg VL muscles

(a)

Time to minimum rSO_2 levels in control leg VM (% of TTF)							
	D2	D3	D4	D5	D6	D7	D8C
S1	95.46%	86.36%	37.93%	55.17%	51.43%	60.61%	29.03%
S2	63.64%	58.33%	63.64%	46.67%	50.00%	61.54%	40.00%
S3	23.08%	15.15%	21.43%	81.08%	21.43%	19.35%	17.14%
S4	23.33%	17.14%	N/A	18.92%	12.24%	11.32%	10.45%
S5	29.41%	38.89%	24.00%	52.63%	33.33%	95.00%	33.33%
S6	15.00%	32.00%	40.00%	50.00%	68.00%	N/A	N/A
S7	34.21%	60.27%	49.33%	40.86%	39.80%	52.50%	6.06%
S8	38.46%	42.86%	37.50%	35.29%	29.41%	27.78%	25.00%
S9	70.00%	58.33%	50.00%	42.86%	53.33%	38.46%	50.00%
S10	57.14%	25.00%	12.50%	66.67%	100.00%	55.56%	11.11%
S11	60.00%	90.00%	58.33%	50.00%	54.55%	81.82%	50.00%
S12	53.85%	54.55%	100.00%	83.33%	100.00%	100.00%	85.71%
S13	60.00%	100.00%	93.33%	94.12%	64.71%	50.00%	68.18%
S14	37.50%	35.71%	40.00%	38.46%	58.33%	40.00%	30.77%

(b)

Time to minimum rSO_2 levels in control leg VL (% of TTF)							
	D2	D3	D4	D5	D6	D7	D8C
S1	100.00%	86.36%	41.38%	58.62%	28.57%	69.70%	25.81%
S2	100.00%	58.33%	100.00%	53.33%	58.33%	53.85%	53.33%
S3	23.08%	18.18%	35.71%	13.51%	21.43%	19.35%	17.14%
S4	23.33%	14.29%	N/A	18.92%	12.24%	11.32%	10.45%
S5	35.29%	38.89%	24.00%	52.63%	33.33%	50.00%	33.33%
S6	20.00%	28.00%	40.00%	31.82%	36.00%	N/A	N/A
S7	10.53%	16.44%	68.00%	81.72%	51.02%	48.33%	13.13%
S8	46.15%	50.00%	37.50%	41.18%	29.41%	27.78%	25.00%
S9	70.00%	58.33%	42.86%	50.00%	53.33%	38.46%	42.86%
S10	71.43%	100.00%	62.50%	66.67%	37.50%	66.67%	33.33%
S11	60.00%	60.00%	50.00%	50.00%	54.55%	54.55%	41.67%
S12	53.85%	54.55%	87.50%	83.33%	85.71%	85.71%	100.00%
S13	40.00%	37.50%	33.33%	35.29%	35.29%	33.33%	31.82%
S14	37.50%	35.71%	53.33%	38.46%	41.67%	60.00%	30.77%

(c)

Time to minimum rSO_2 levels in treatment leg VM (% of TTF)							
	D2	D3	D4	D5	D6	D7	D8T
S1	44.000%	100.00%	90.00%	28.13%	83.33%	90.00%	96.15%
S2	63.636%	54.55%	50.00%	42.86%	46.15%	46.67%	29.41%
S3	77.778%	86.05%	90.24%	82.00%	96.43%	86.67%	91.94%
S4	13.043%	16.36%	14.49%	14.89%	14.81%	88.75%	9.23%
S5	38.889%	47.37%	25.00%	28.57%	22.73%	42.86%	58.33%
S6	26.316%	24.00%	36.84%	32.00%	15.15%	N/A	N/A
S7	69.333%	27.78%	47.56%	38.95%	50.89%	37.29%	26.42%
S8	38.462%	35.71%	31.25%	31.25%	100.00%	100.00%	100.00%
S9	50.000%	50.00%	42.86%	37.50%	50.00%	50.00%	46.15%
S10	71.429%	100.00%	85.71%	77.78%	100.00%	77.78%	71.43%
S11	40.000%	44.44%	45.45%	55.56%	55.56%	50.00%	50.00%
S12	92.857%	78.57%	100.00%	100.00%	100.00%	100.00%	75.00%
S13	80.000%	83.33%	93.75%	81.25%	93.75%	34.78%	100.00%
S14	N/A	20.00%	41.67%	30.77%	36.36%	21.43%	21.43%

(d)

Time to minimum rSO_2 levels in treatment leg VL (% of TTF)							
	D2	D3	D4	D5	D6	D7	D8T
S1	32.00%	100.00%	53.33%	28.13%	36.67%	30.00%	61.54%
S2	63.64%	100.00%	100.00%	100.00%	69.23%	100.00%	58.82%
S3	25.93%	13.95%	14.63%	14.00%	98.21%	10.00%	91.94%
S4	13.04%	10.91%	8.70%	12.77%	12.96%	7.50%	10.77%
S5	38.89%	31.58%	50.00%	38.10%	36.36%	66.67%	29.17%
S6	31.58%	28.00%	36.84%	32.00%	24.24%	N/A	N/A
S7	81.33%	43.06%	32.93%	88.42%	52.68%	24.58%	15.09%
S8	38.46%	57.14%	37.50%	37.50%	27.78%	33.33%	30.00%
S9	58.33%	66.67%	50.00%	43.75%	58.33%	50.00%	46.15%
S10	85.71%	71.43%	85.71%	55.56%	100.00%	55.56%	71.43%
S11	60.00%	77.78%	72.73%	66.67%	66.67%	70.00%	60.00%
S12	50.00%	64.29%	100.00%	85.71%	100.00%	57.14%	62.50%
S13	100.00%	41.67%	37.50%	43.75%	87.50%	100.00%	40.00%
S14	N/A	30.00%	33.33%	38.46%	54.55%	35.71%	35.71%

Table E- 2: The statistic results for hypothesis 5a (the acute KT application), 5b (duration of KT application), 5c (KT application residual effect). (a) VM muscles. (b) VL muscles

(a) VM muscles

Hypothesis	Day difference	Mean difference	S.D. difference	*p-value*	Power
H5a. Acute of KT application	D3-D2	0.033	0.224	*0.609*	8.0%
H5b. Duration of KT application	D4-D3	0.019	0.138	*0.613*	7.7%
	D5-D3	-0.062	0.227	*0.326*	15.7%
	D6-D3	0.069	0.217	*0.253*	19.9%
H5c. Residual after KT application	D7-D2	0.104	0.356	*0.332*	17.4%
	D7-D6	-0.018	0.294	*0.826*	5.5%

* indicates statistical significance between mean time to minimum rSO_2 levels in the trial for each hypothesis comparison
▲ presents the Power is greater than 80%

(b) VL muscles

Hypothesis	Day difference	Mean difference	S.D. difference	*p-value*	Power
H5a. Acute of KT application	D3-D2	0.021	0.318	*0.814*	5.6%
H5b. Duration of KT application	D4-D3	-0.017	0.193	*0.753*	6.0%
	D5-D3	-0.037	0.262	*0.607*	7.8%
	D6-D3	0.063	0.367	*0.529*	9.2%
H5c. Residual after KT application	D7-D2	-0.036	0.245	*0.626*	7.9%
	D7-D6	-0.123	0.329	*0.201*	25.6%

* indicates statistical significance between mean time to minimum rSO_2 levels in the trial for each hypothesis comparison
▲ presents the Power is greater than 80%

Appendix F: rSO_2 Levels in VM/VL Muscle During the Isotonic Flexion/Extension Exercise

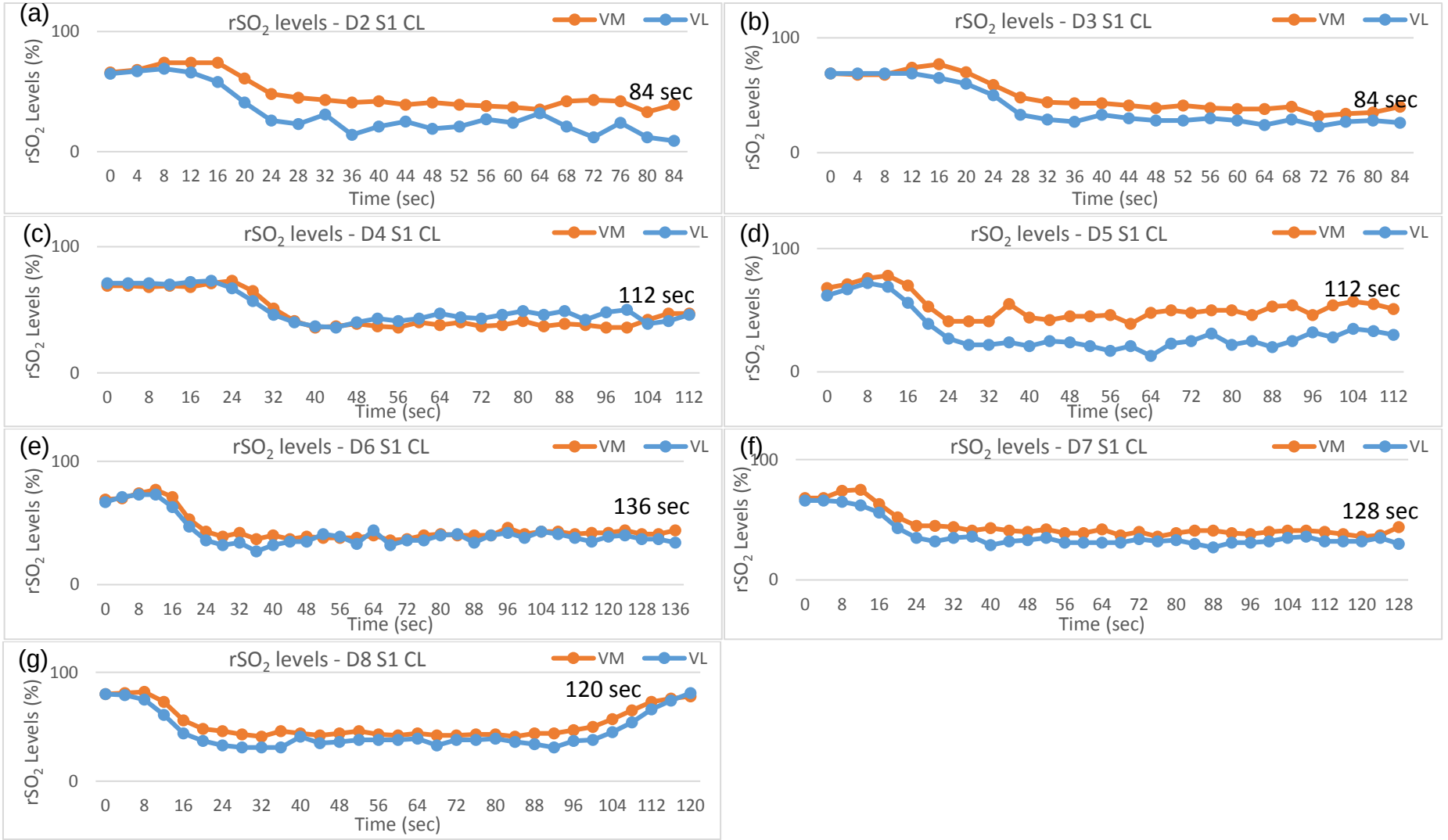

Figure F- 1: The rSO_2 levels in control leg VM and VL during isotonic exercise from D2 to D8 in Subject 1. (a) D2 (b) D3 (c) D4 (d) D5 (e) D6 (f) D7 (g) D8. The time displayed in the graph is the respective end of that trial

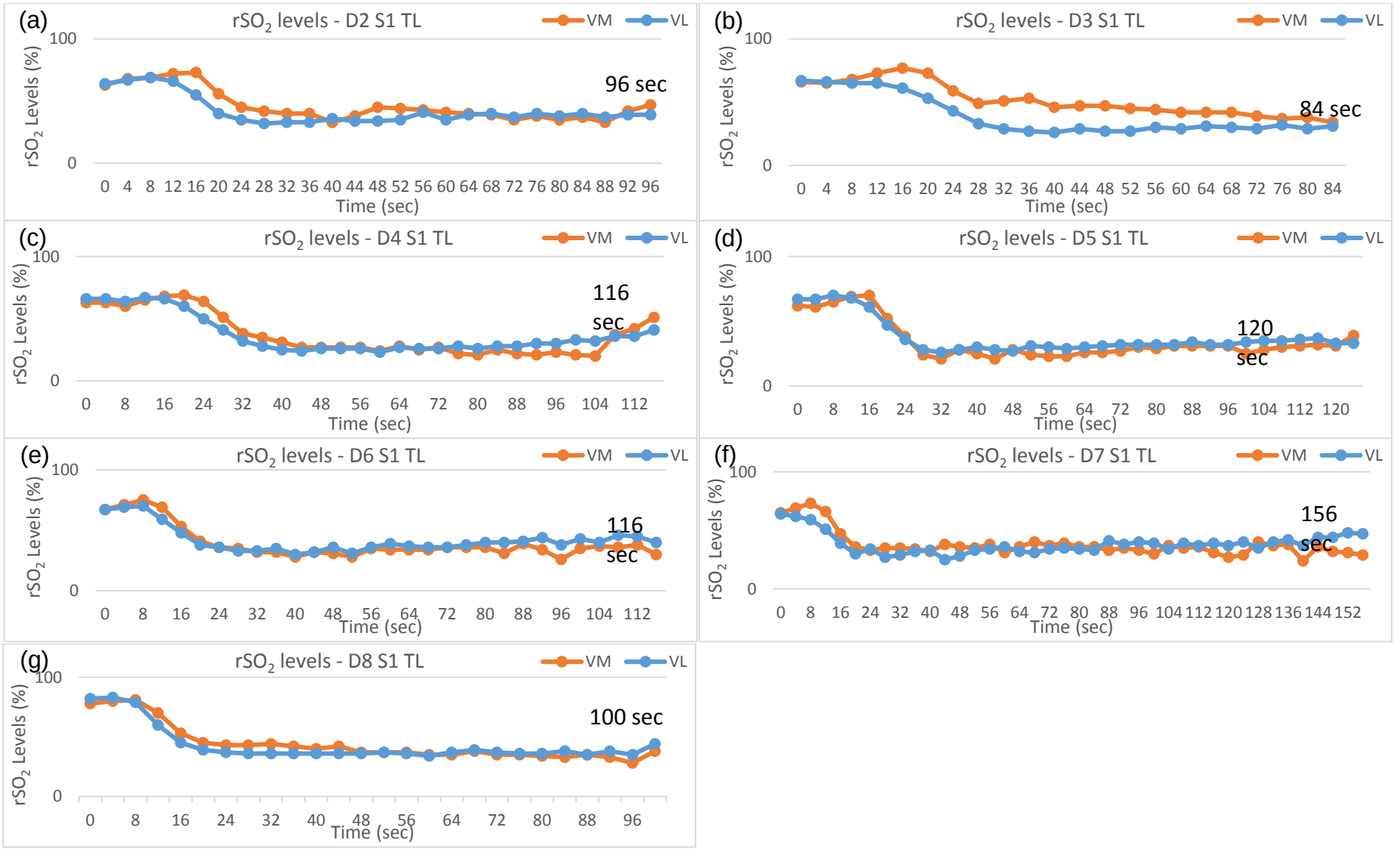

Figure F- 2: The rSO_2 levels treatment leg VM and VL during isotonic exercise from D2 to D8 in Subject 1. (a) D2 (b) D3 (c) D4 (d) D5 (e) D6 (f) D7 (g) D8. The time displayed in the graph is the respective end of that trial

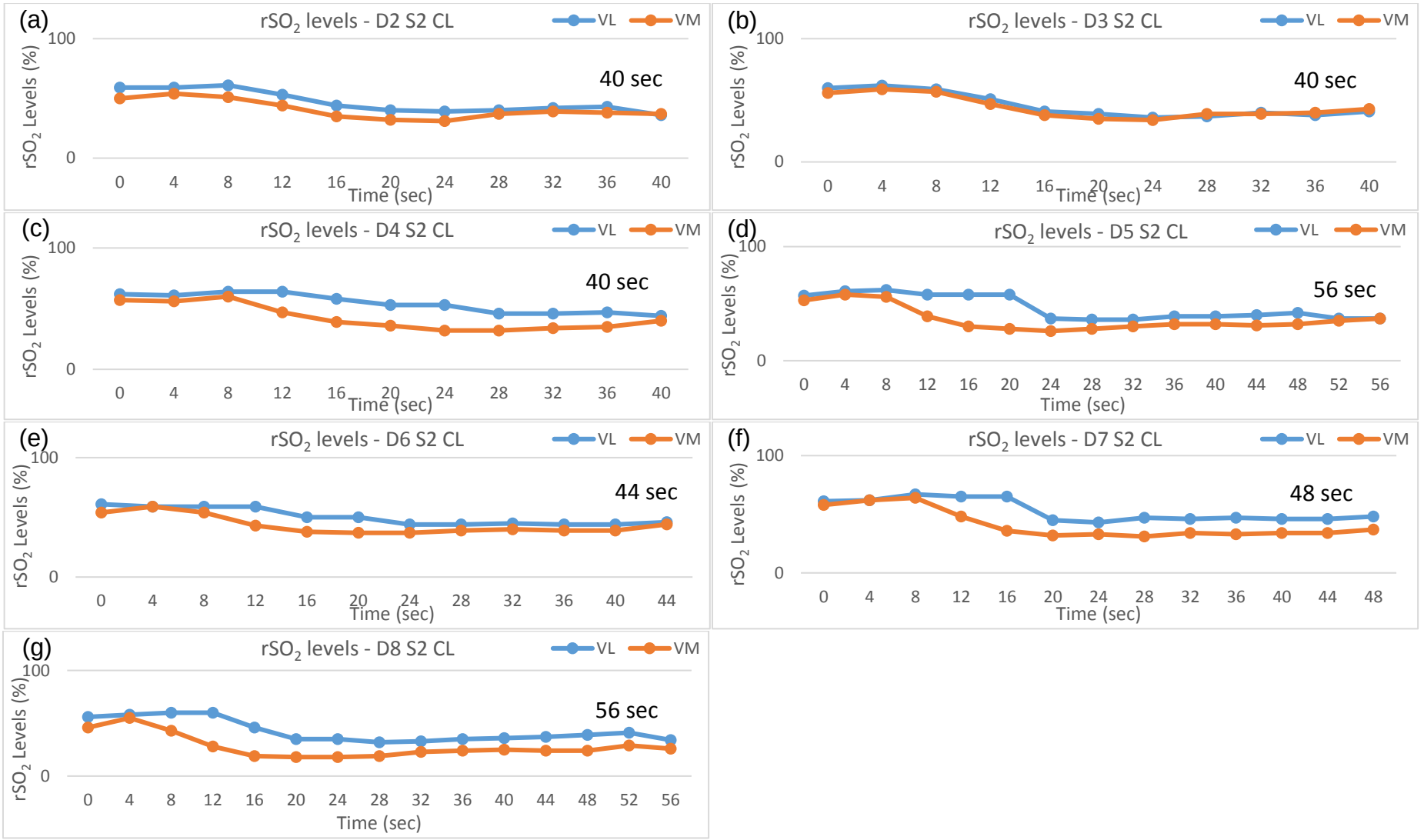

Figure F- 3: The rSO_2 levels control leg VM and VL during isotonic exercise from D2 to D8 in Subject 2. (a) D2 (b) D3 (c) D4 (d) D5 (e) D6 (f) D7 (g) D8. The time displayed in the graph is the respective end of that trial

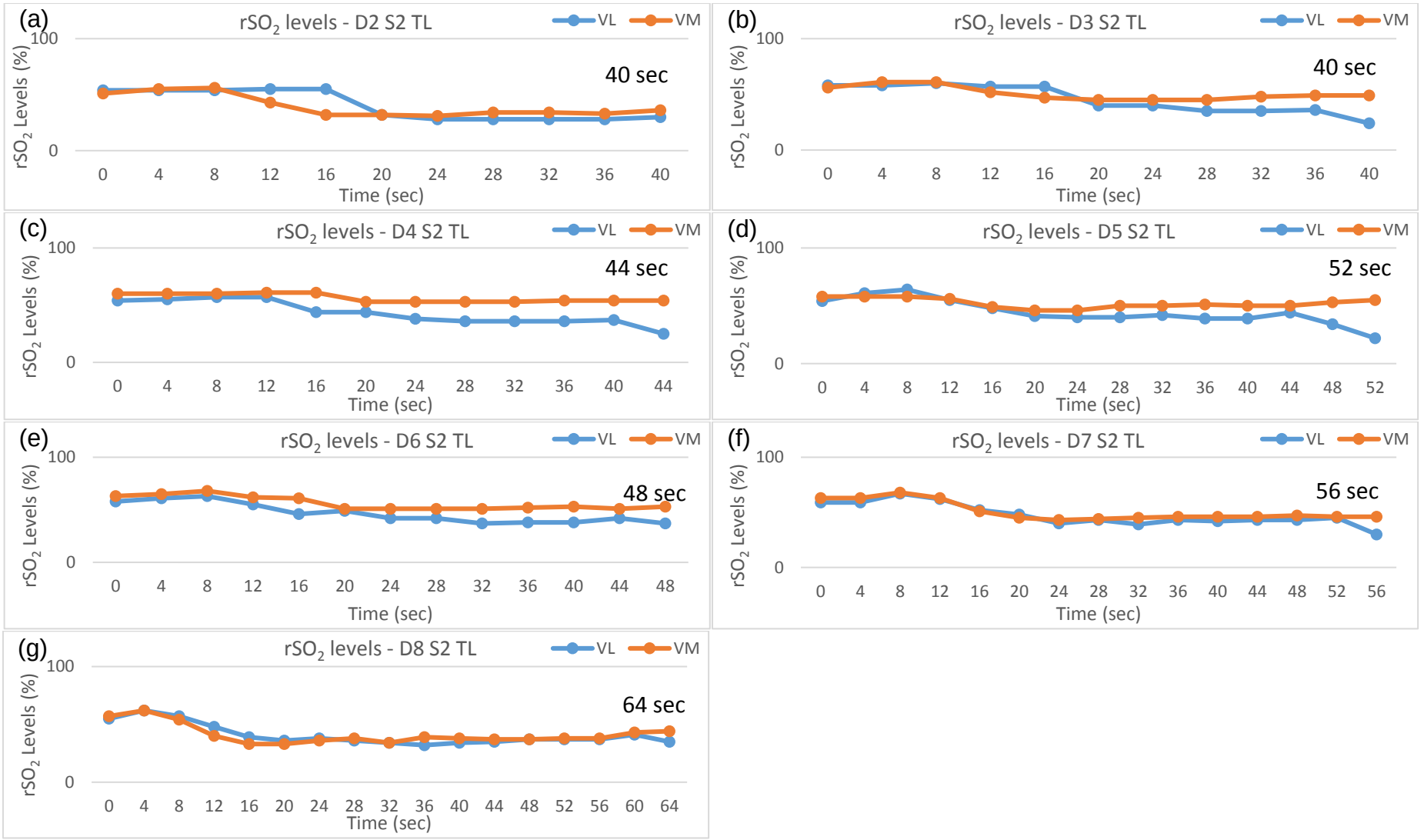

Figure F- 4: The rSO_2 levels treatment leg VM and VL during isotonic exercise from D2 to D8 in Subject 2. (a) D2 (b) D3 (c) D4 (d) D5 (e) D6 (f) D7 (g) D8. The time displayed in the graph is the respective end of that trial

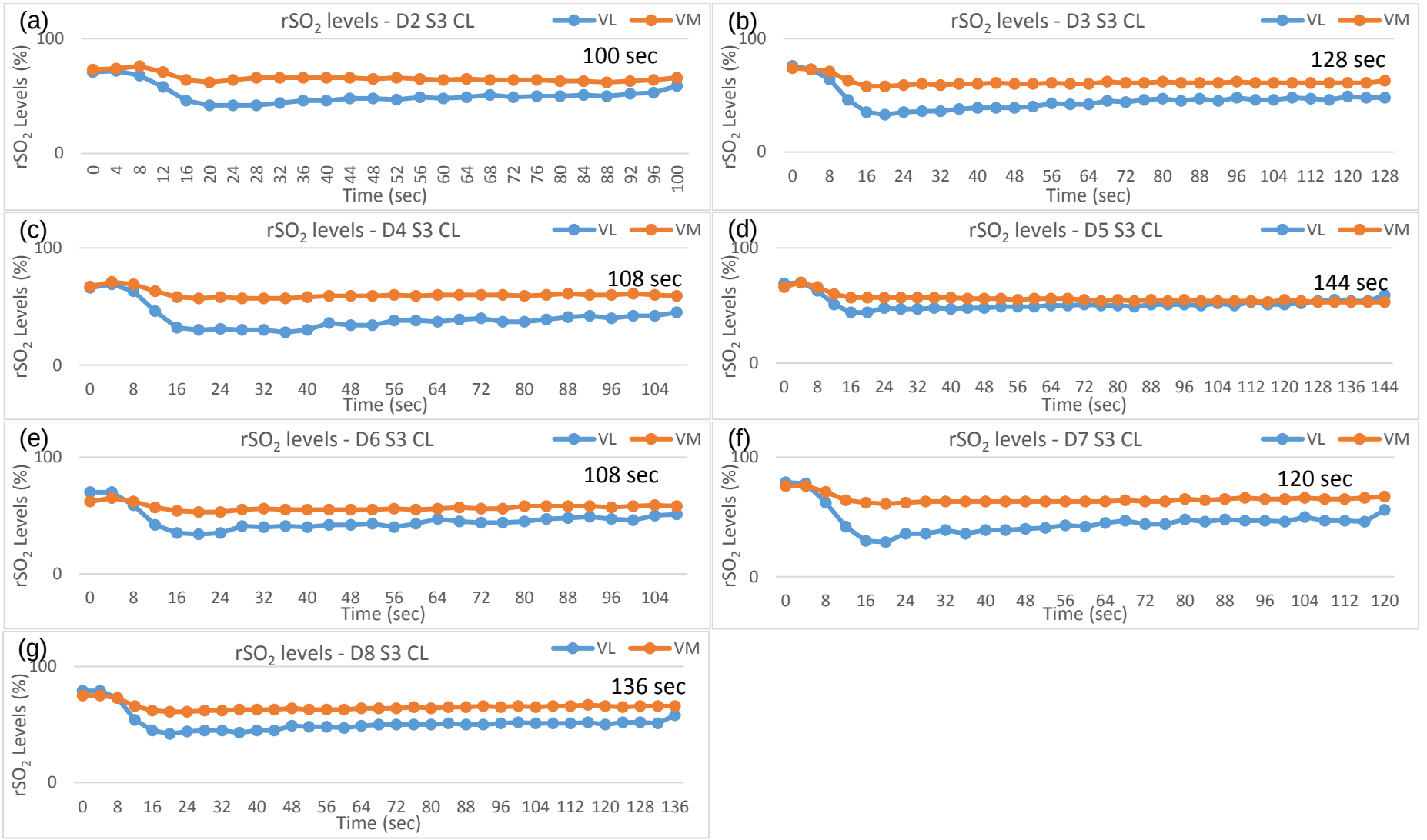

Figure F- 5: The rSO_2 levels control leg VM and VL during isotonic exercise from D2 to D8 in Subject 3. (a) D2 (b) D3 (c) D4 (d) D5 (e) D6 (f) D7 (g) D8. The time displayed in the graph is the respective end of that trial

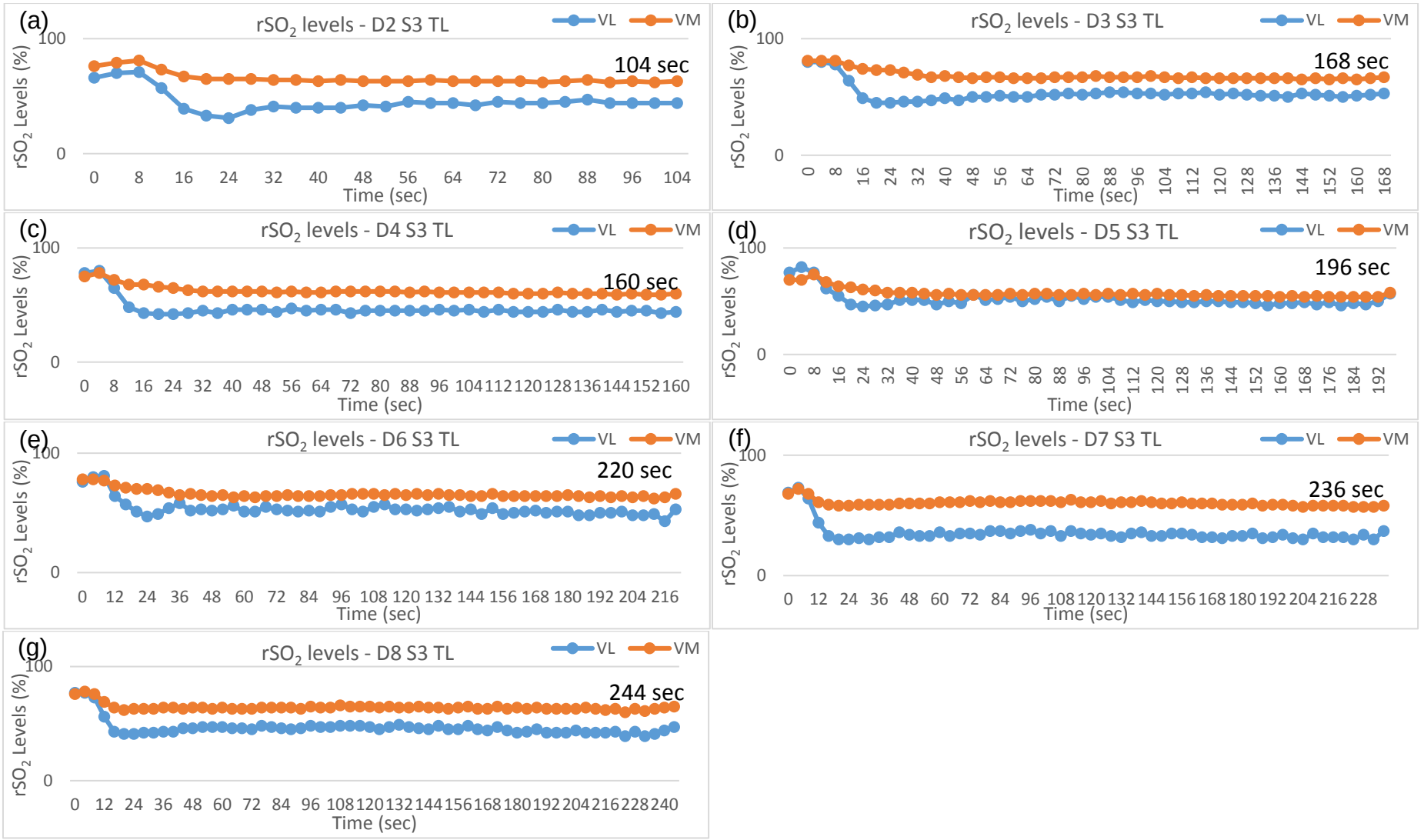

Figure F- 6: The rSO_2 levels treatment leg VM and VL during isotonic exercise from D2 to D8 in Subject 3. (a) D2 (b) D3 (c) D4 (d) D5 (e) D6 (f) D7 (g) D8. The time displayed in the graph is the respective end of that trial

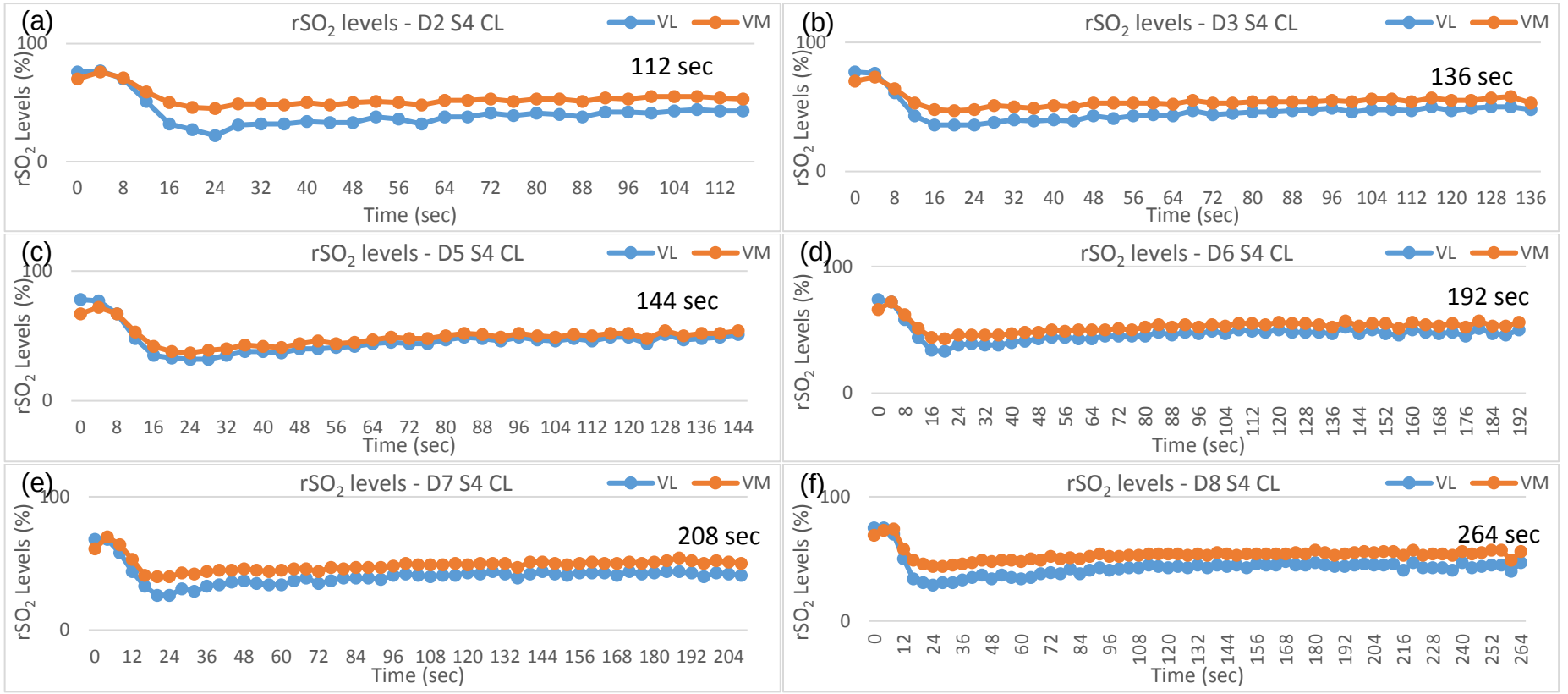

Figure F- 7: The rSO_2 levels control leg VM and VL during isotonic exercise (no D4 data) in Subject 4. (a) D2 (b) D3 (c) D5 (d) D6 (e) D7 (f) D8. The time displayed in the graph is the respective end of that trial

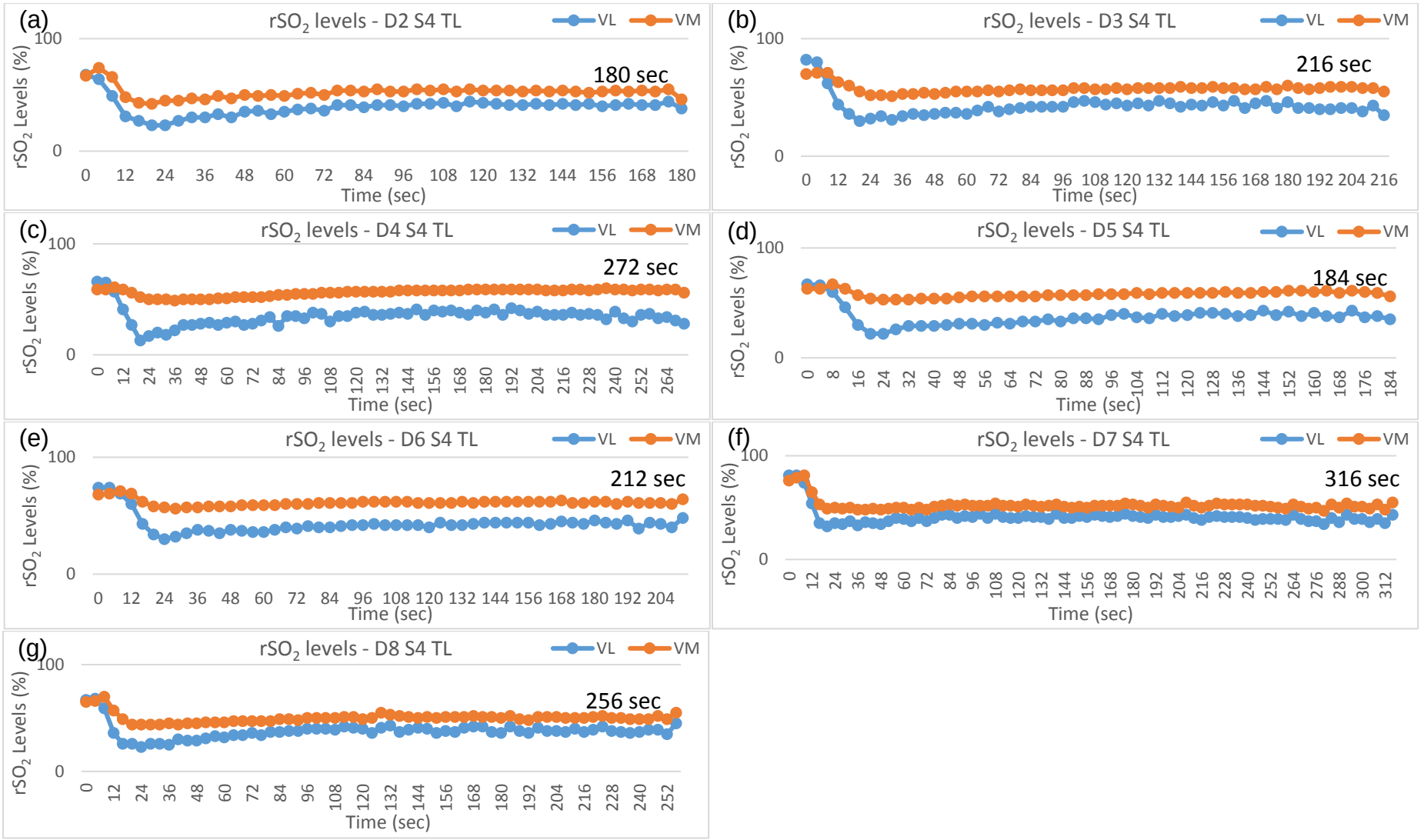

Figure F- 8: The rSO_2 levels treatment leg VM and VL during isotonic exercise from D2 to D8 in Subject 4. (a) D2 (b) D3 (c) D4 (d) D5 (e) D6 (f) D7 (g) D8. The time displayed in the graph is the respective end of that trial

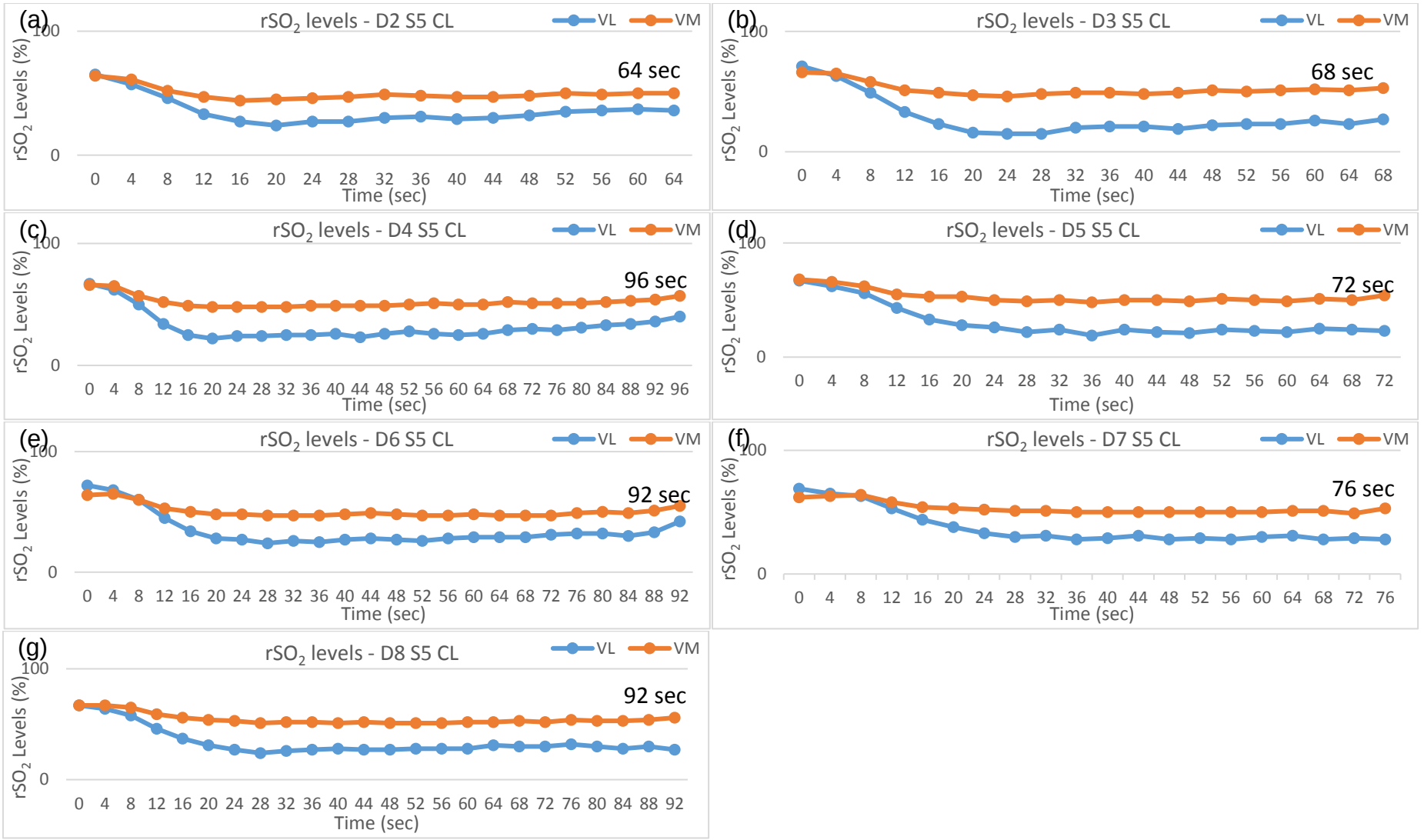

Figure F- 9: The rSO_2 levels control leg VM and VL during isotonic exercise from D2 to D8 in Subject 5. (a) D2 (b) D3 (c) D4 (d) D5 (e) D6 (f) D7 (g) D8. The time displayed in the graph is the respective end of that trial

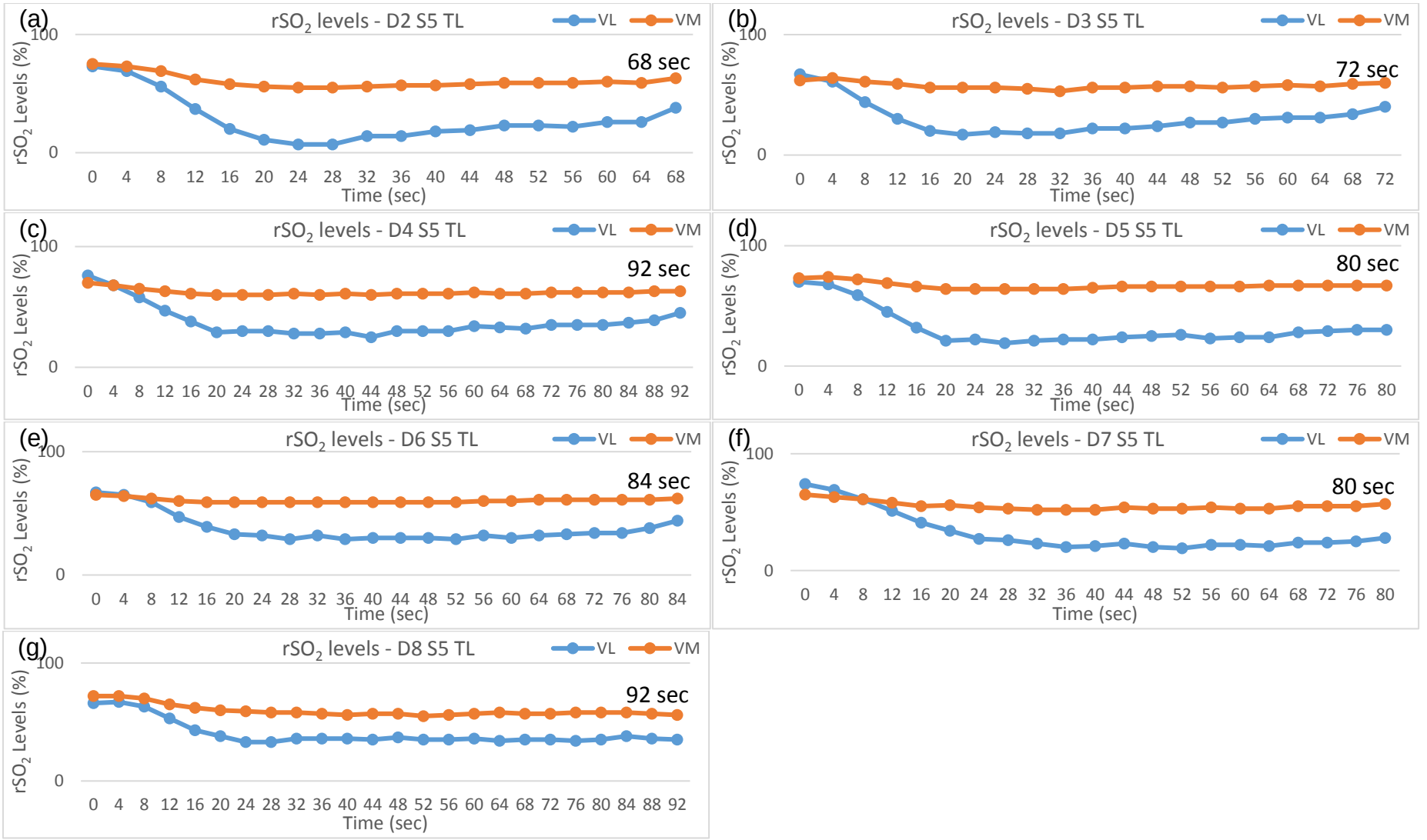

Figure F- 10: The rSO_2 levels treatment leg VM and VL during isotonic exercise from D2 to D8 in Subject 5. (a) D2 (b) D3 (c) D4 (d) D5 (e) D6 (f) D7 (g) D8. The time displayed in the graph is the respective end of that trial

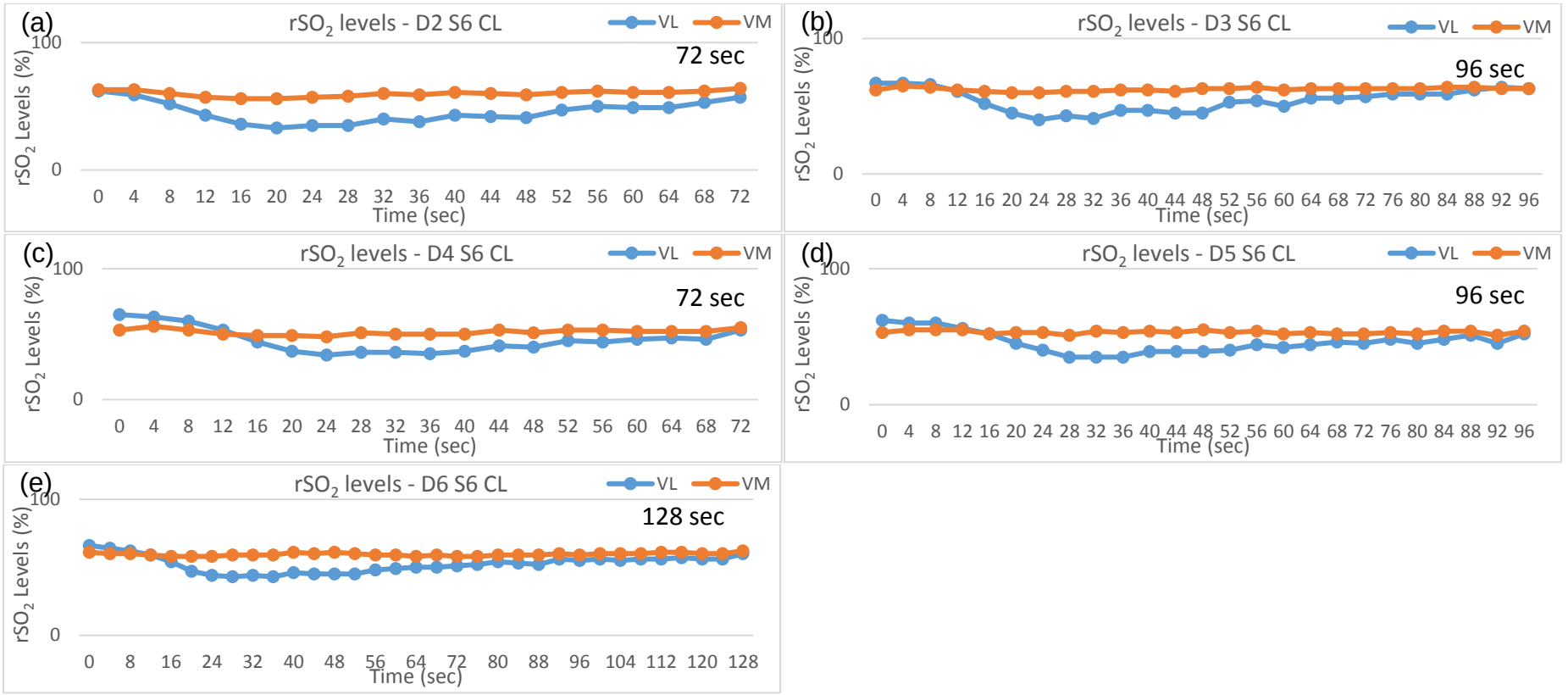

Figure F- 11: The rSO_2 levels control leg VM and VL during isotonic exercise from D2 to D6 in Subject 6. (a) D2 (b) D3 (c) D4 (d) D5 (e) D6. The time displayed in the graph is the respective end of that trial

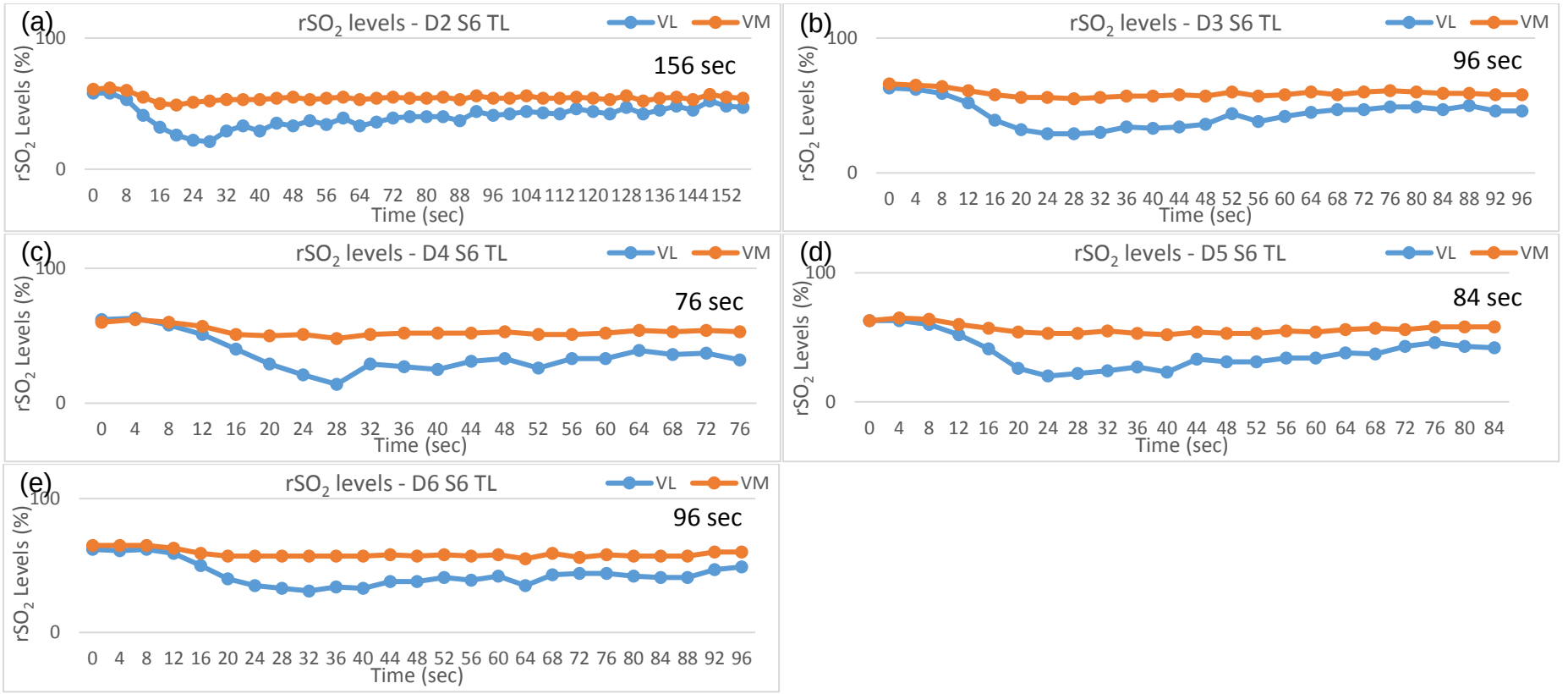

Figure F- 12: The rSO_2 levels treatment leg VM and VL during isotonic exercise from D2 to D6 in Subject 6. (a) D2 (b) D3 (c) D4 (d) D5 (e) D6. The time displayed in the graph is the respective end of that trial

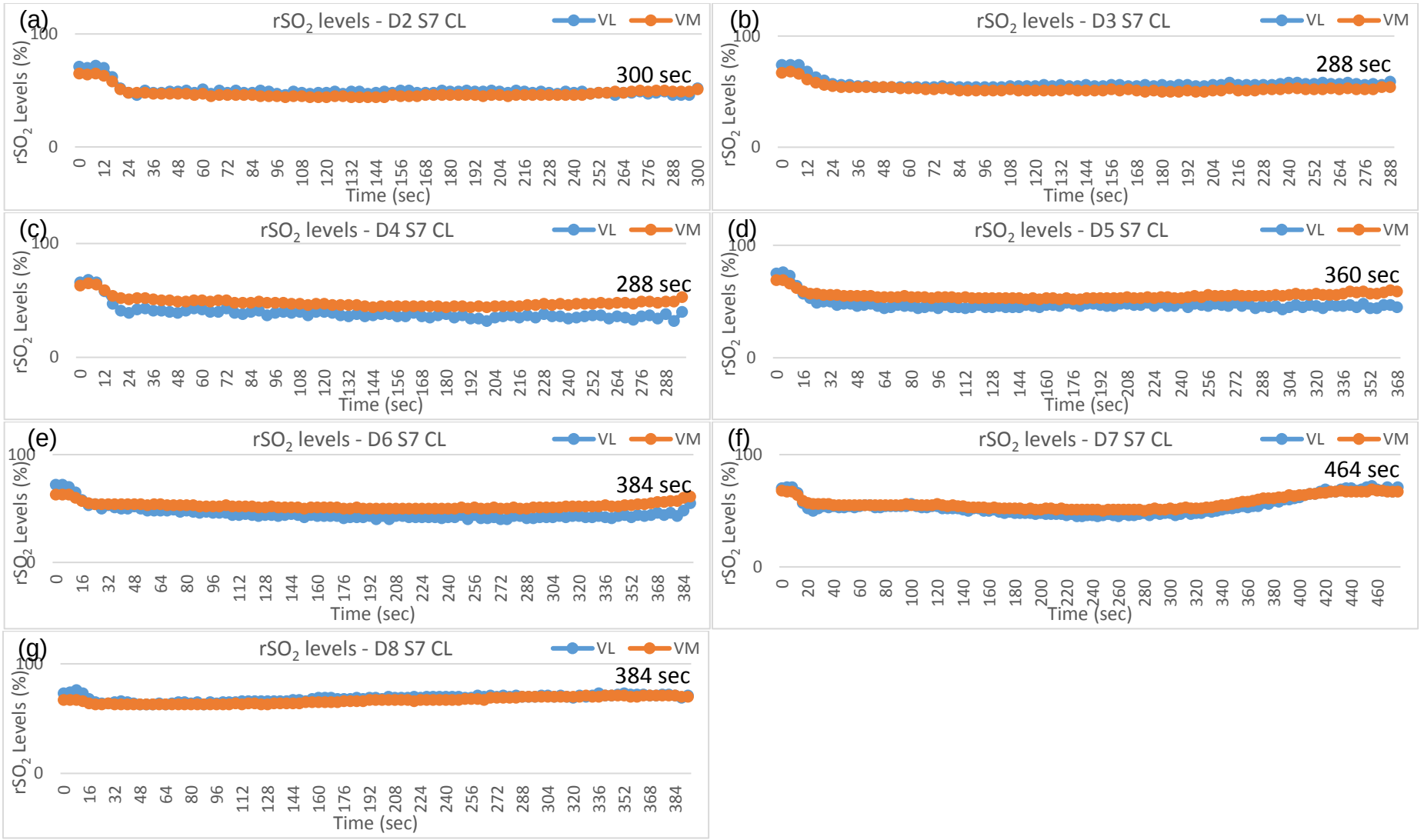

Figure F- 13: The rSO_2 levels control leg VM and VL during isotonic exercise from D2 to D8 in Subject 7. (a) D2 (b) D3 (c) D4 (d) D5 (e) D6 (f) D7 (g) D8. The time displayed in the graph is the respective end of that trial

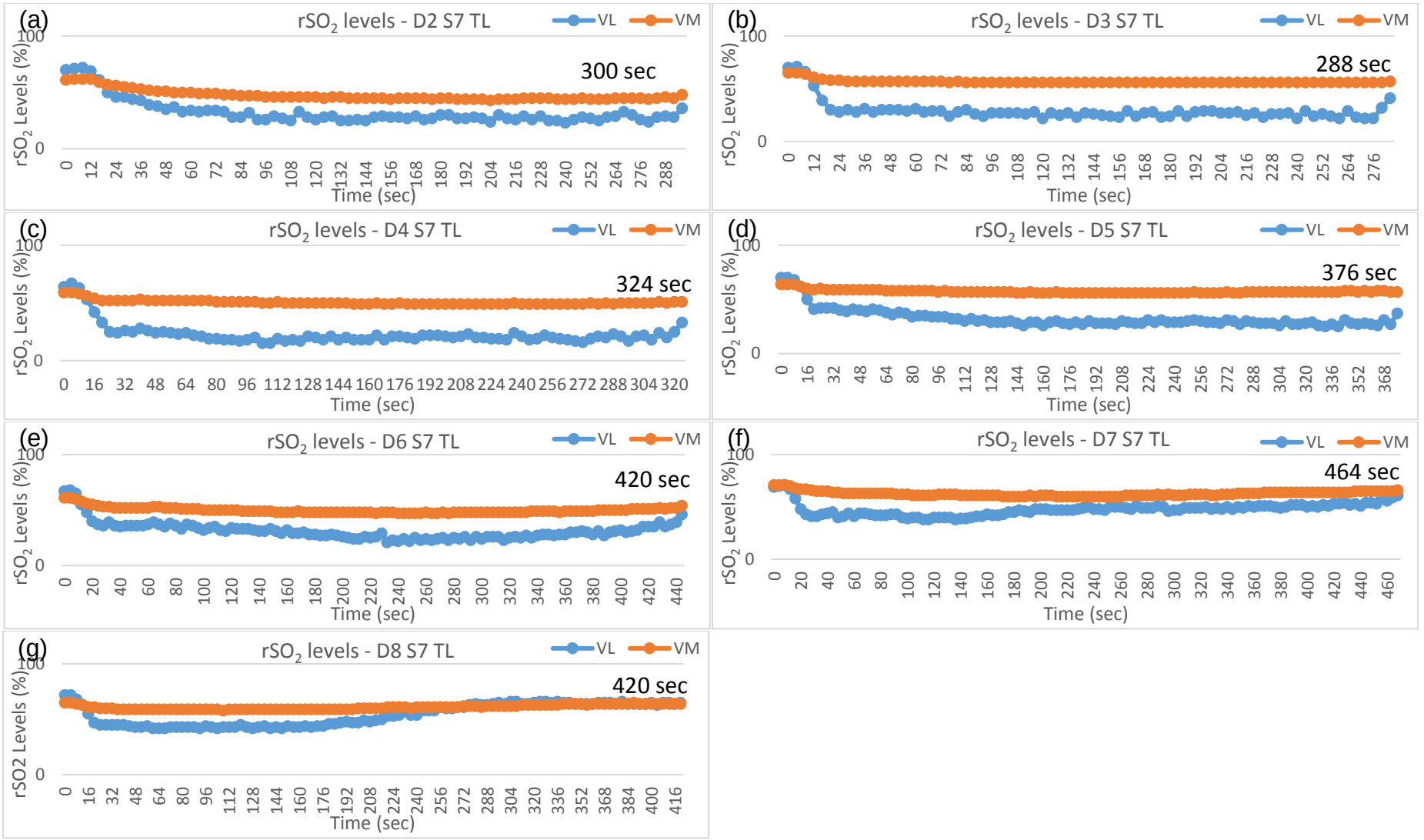

Figure F- 14: The rSO_2 levels treatment leg VM and VL during isotonic exercise from D2 to D8 in Subject 7. (a) D2 (b) D3 (c) D4 (d) D5 (e) D6 (f) D7 (g) D8. The time displayed in the graph is the respective end of that trial

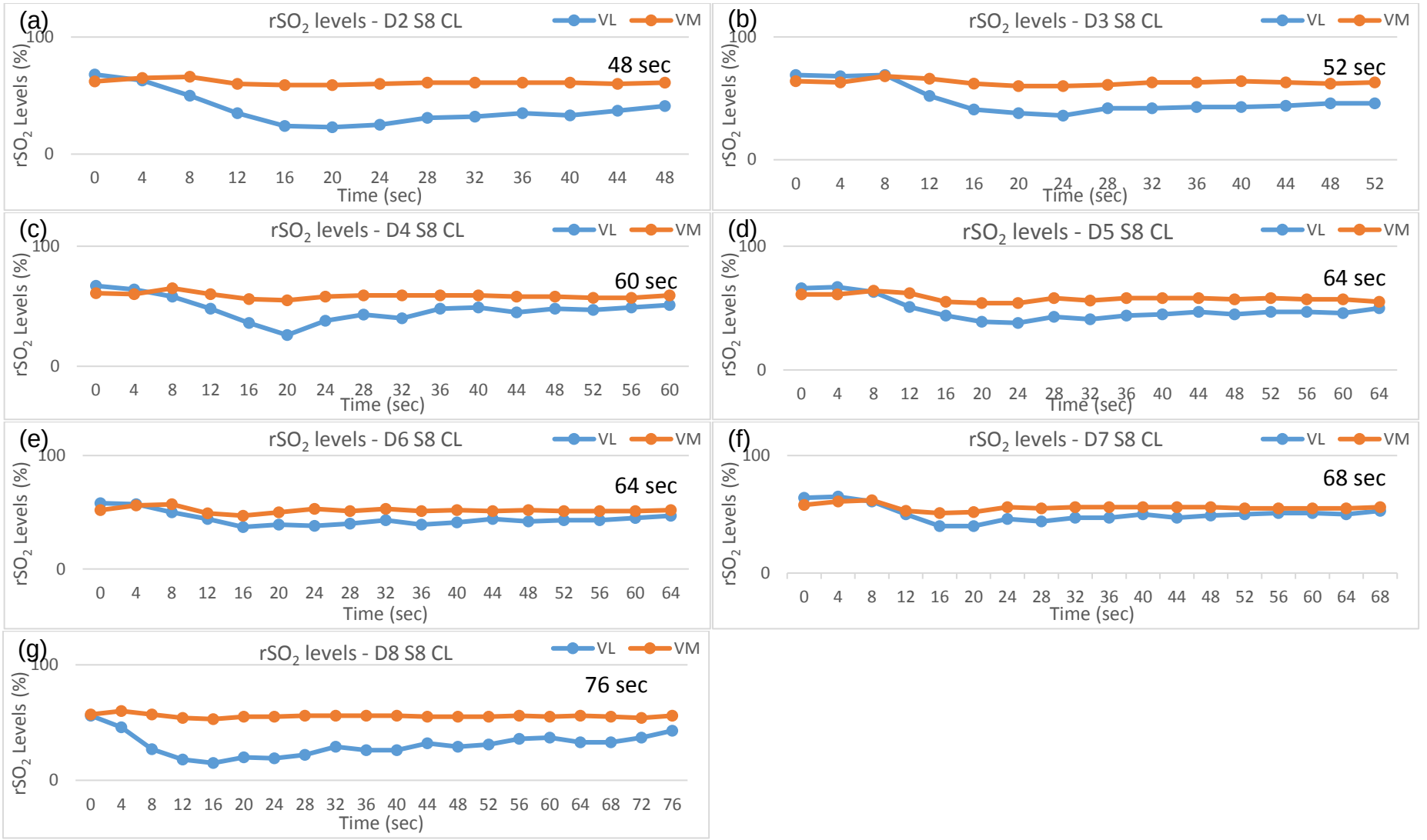

Figure F- 15: The rSO_2 levels control leg VM and VL during isotonic exercise from D2 to D8 in Subject 8. (a) D2 (b) D3 (c) D4 (d) D5 (e) D6 (f) D7 (g) D8. The time displayed in the graph is the respective end of that trial

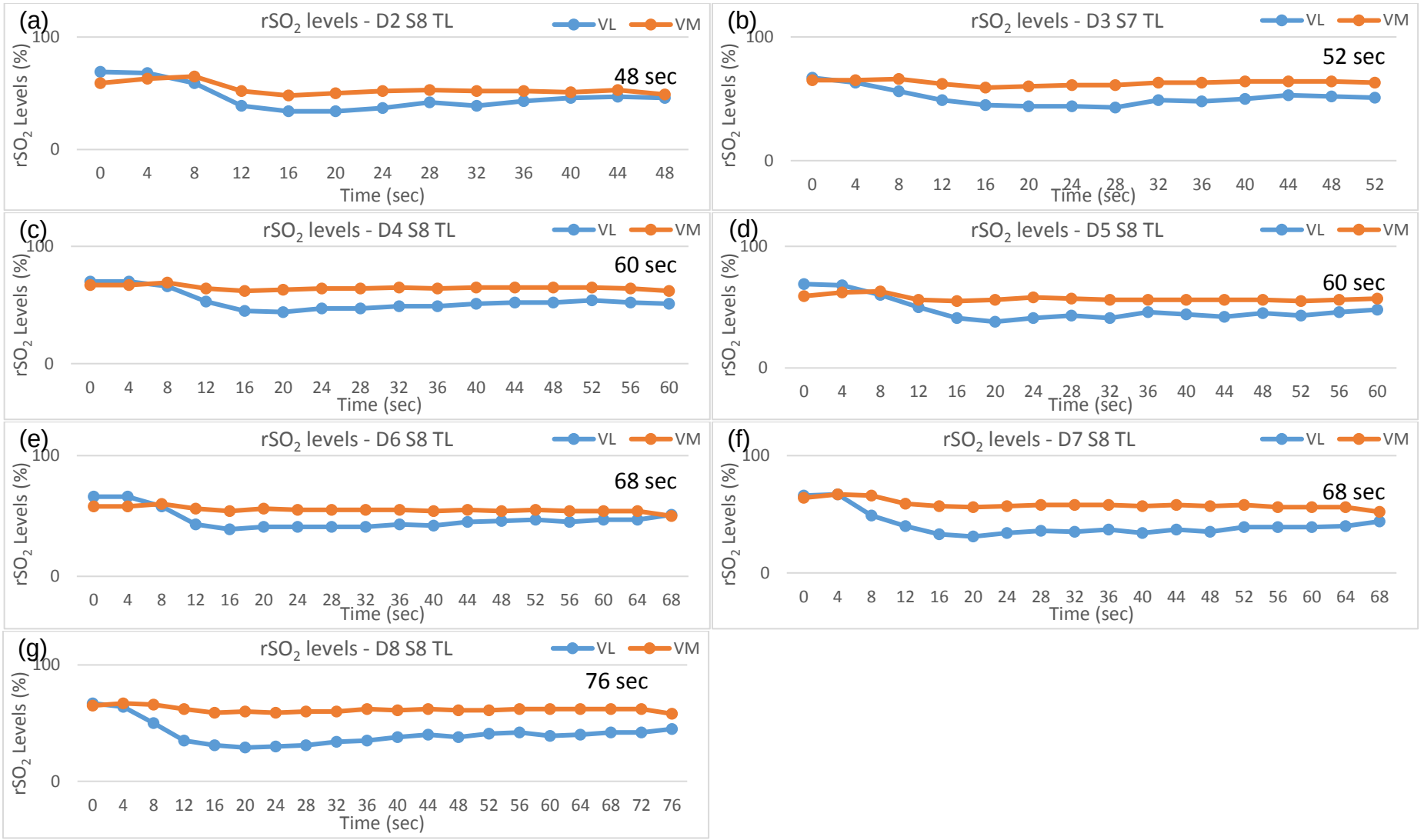

Figure F- 16: The rSO_2 levels treatment leg VM and VL during isotonic exercise from D2 to D8 in Subject 8. (a) D2 (b) D3 (c) D4 (d) D5 (e) D6 (f) D7 (g) D8. The time displayed in the graph is the respective end of that trial

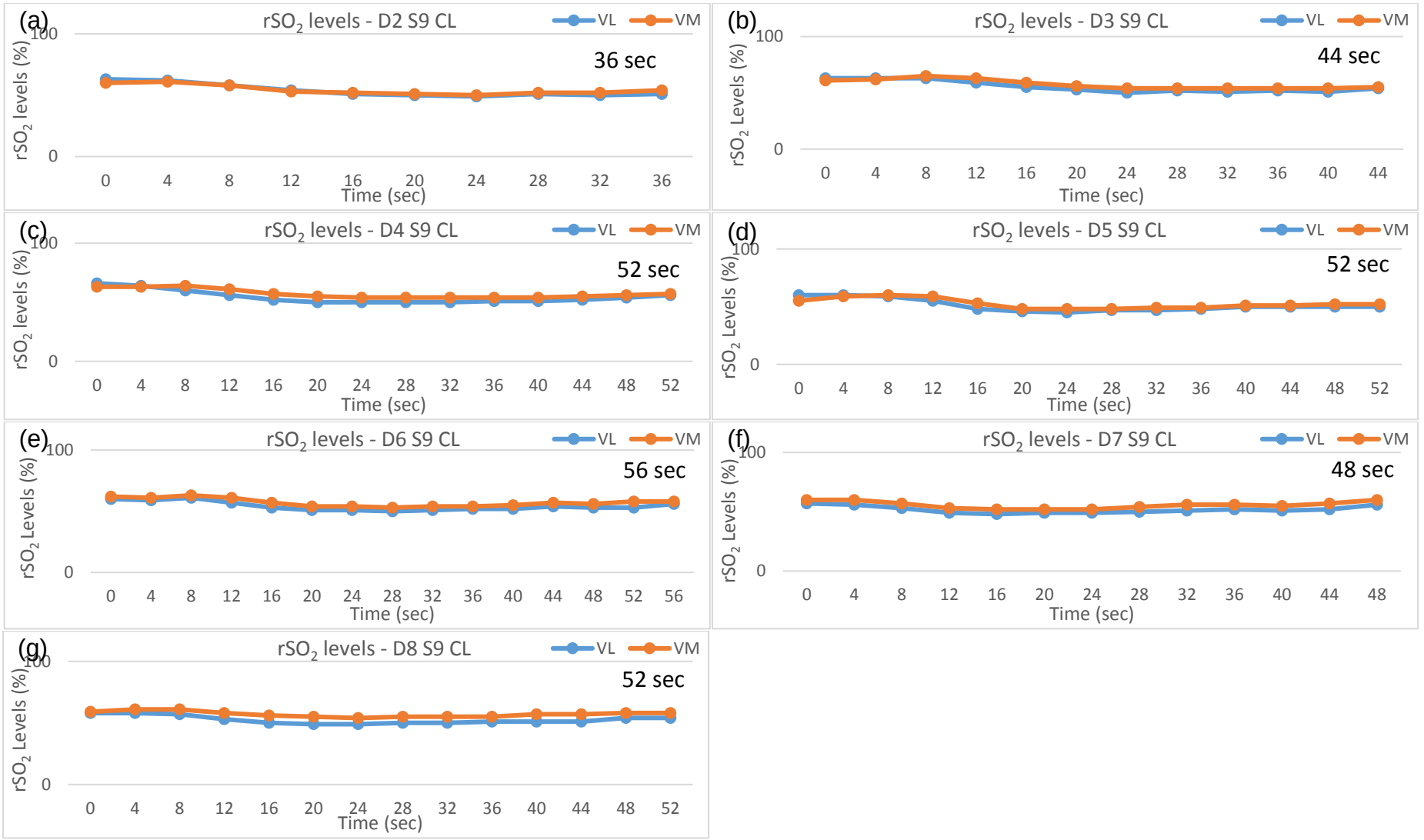

Figure F- 17: The rSO_2 levels control leg VM and VL during isotonic exercise from D2 to D8 in Subject 9. (a) D2 (b) D3 (c) D4 (d) D5 (e) D6 (f) D7 (g) D8. The time displayed in the graph is the respective end of that trial

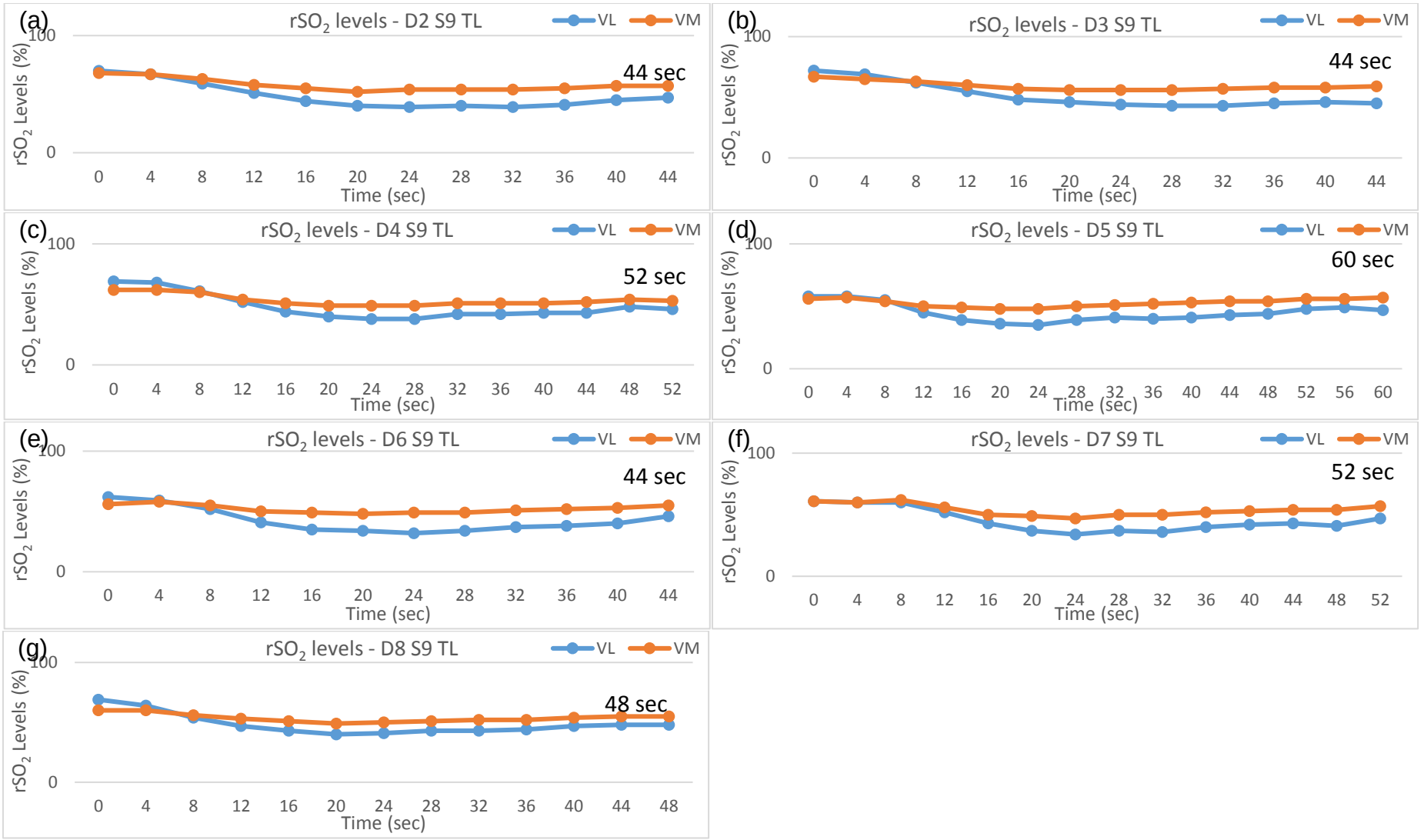

Figure F- 18: The rSO_2 levels treatment leg VM and VL during isotonic exercise from D2 to D8 in Subject 9. (a) D2 (b) D3 (c) D4 (d) D5 (e) D6 (f) D7 (g) D8. The time displayed in the graph is the respective end of that trial

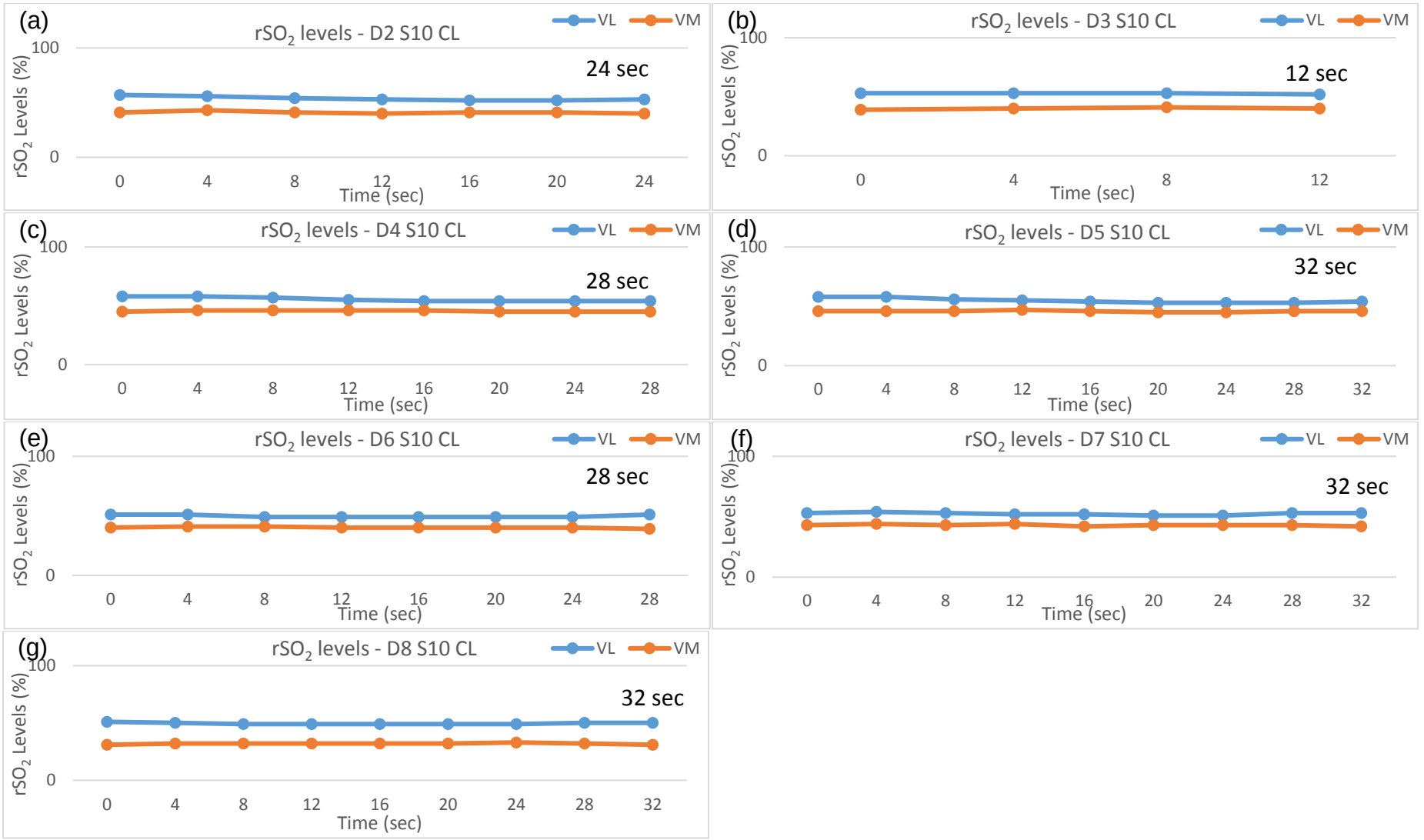

Figure F- 19: The rSO_2 levels control leg VM and VL during isotonic exercise from D2 to D8 in Subject 10. (a) D2 (b) D3 (c) D4 (d) D5 (e) D6 (f) D7 (g) D8. The time displayed in the graph is the respective end of that trial

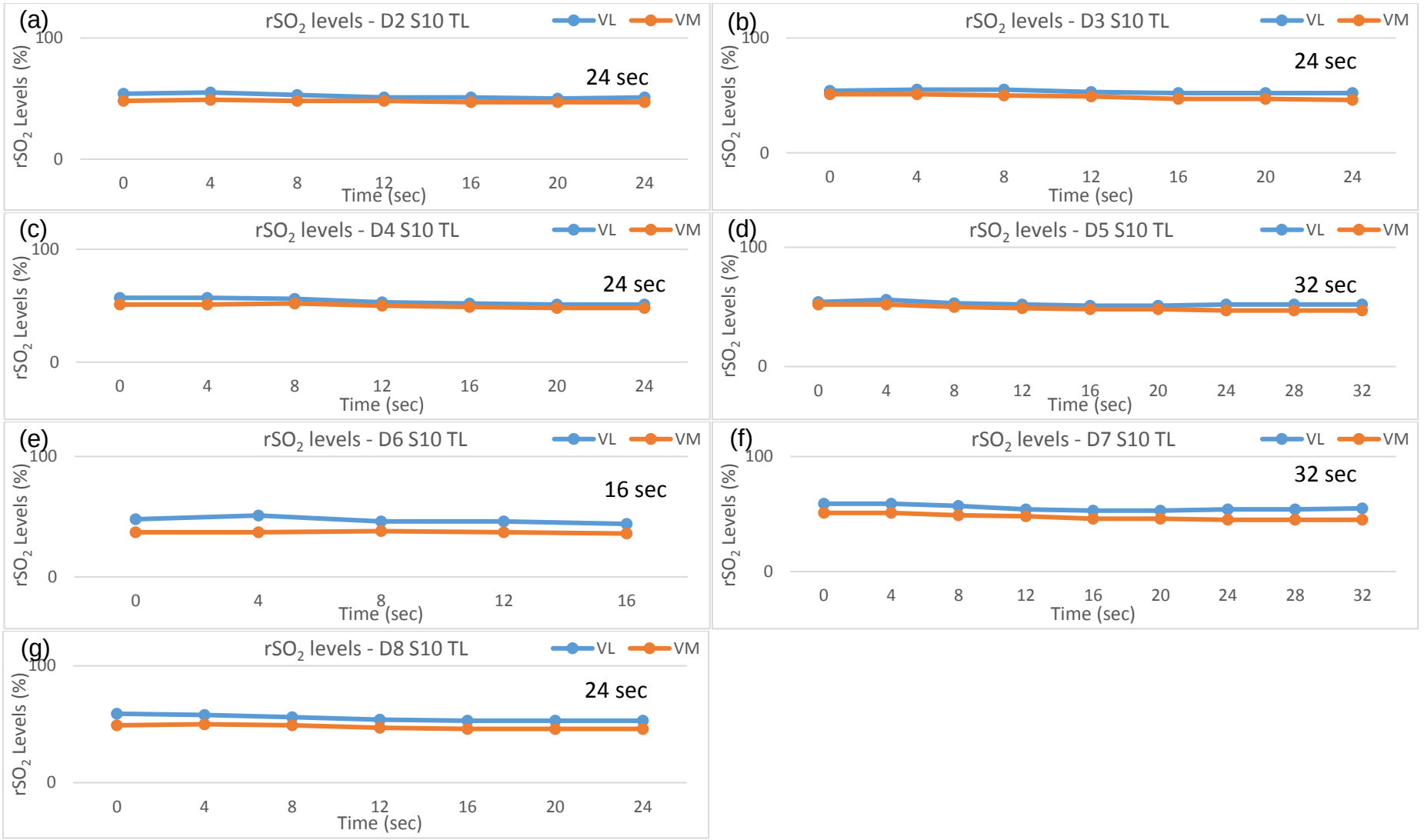

Figure F- 20: The rSO_2 levels treatment leg VM and VL during isotonic exercise from D2 to D8 in Subject 10. (a) D2 (b) D3 (c) D4 (d) D5 (e) D6 (f) D7 (g) D8. The time displayed in the graph is the respective end of that trial

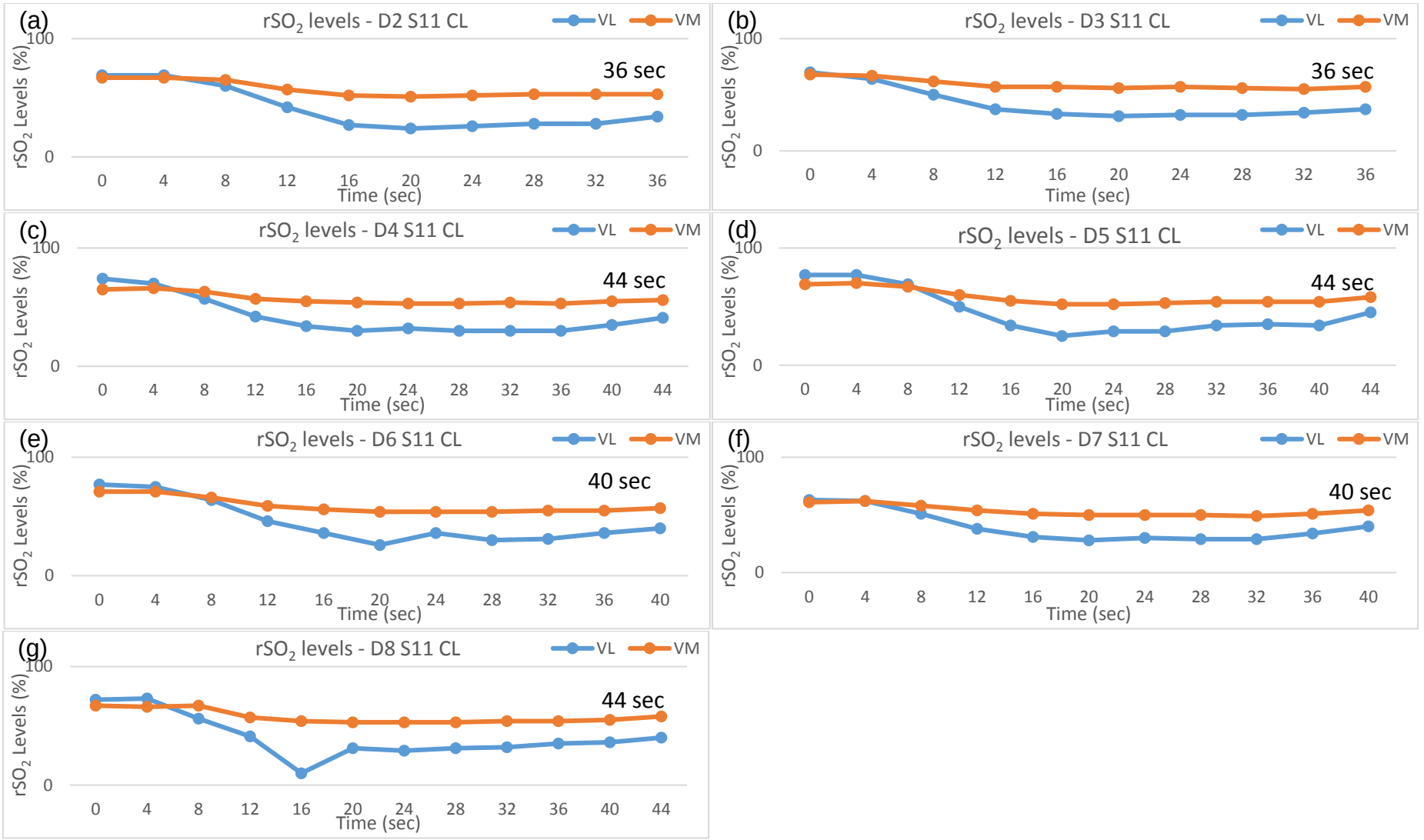

Figure F- 21: The rSO_2 levels control leg VM and VL during isotonic exercise from D2 to D8 in Subject 11. (a) D2 (b) D3 (c) D4 (d) D5 (e) D6 (f) D7 (g) D8. The time displayed in the graph is the respective end of that trial

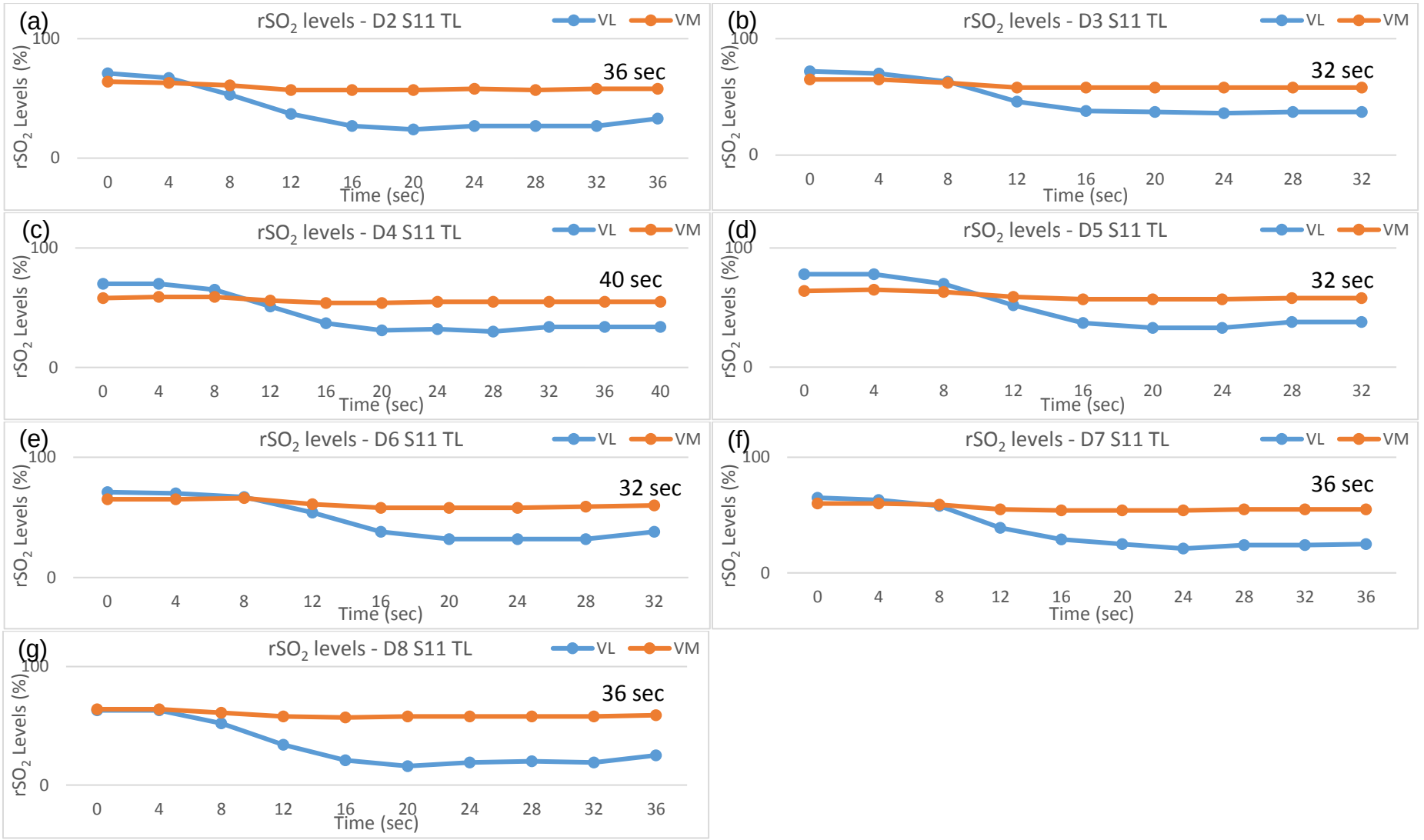

Figure F- 22: The rSO_2 levels treatment leg VM and VL during isotonic exercise from D2 to D8 in Subject 11. (a) D2 (b) D3 (c) D4 (d) D5 (e) D6 (f) D7 (g) D8. The time displayed in the graph is the respective end of that trial

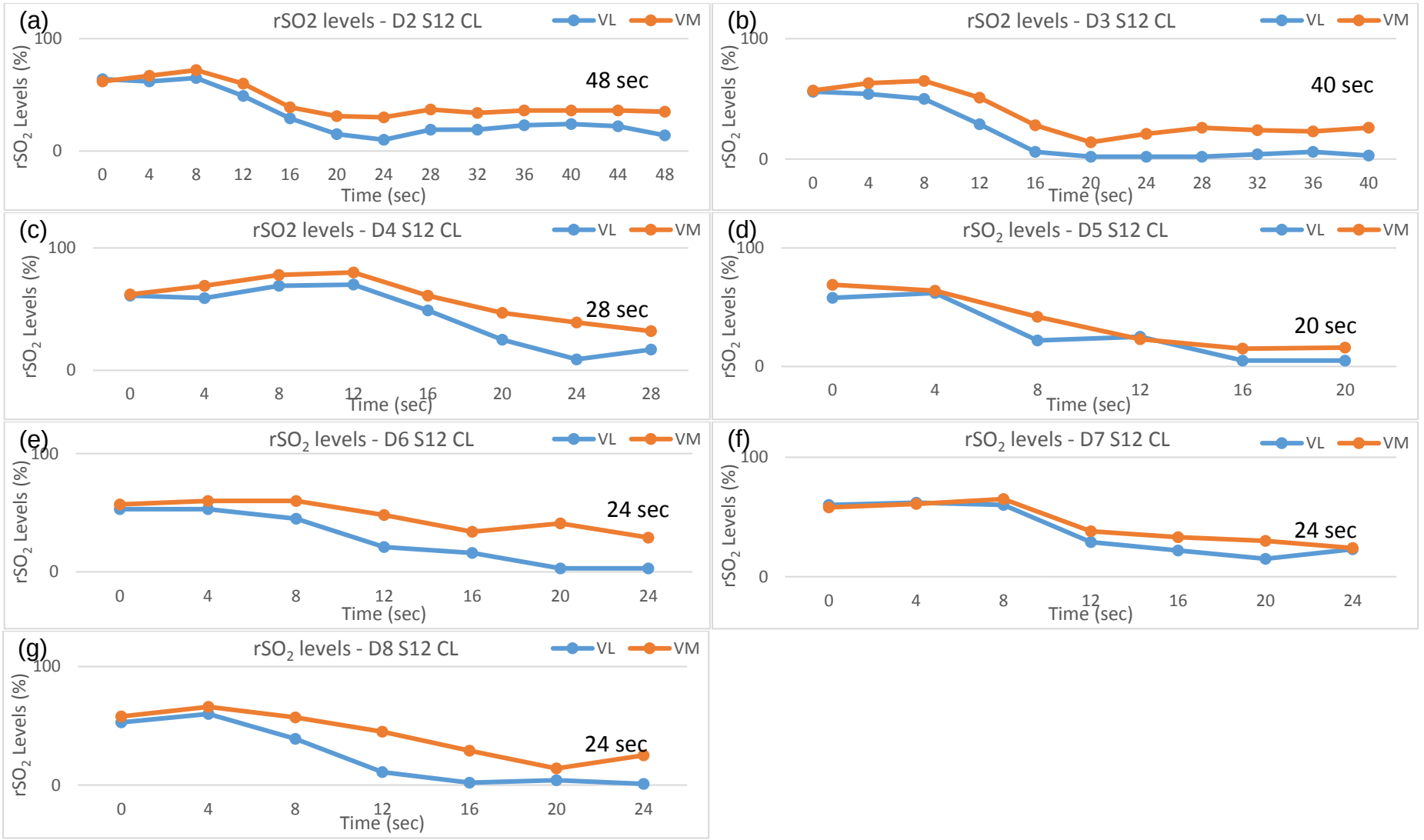

Figure F- 23: The rSO_2 levels control leg VM and VL during isotonic exercise from D2 to D8 in Subject 12. (a) D2 (b) D3 (c) D4 (d) D5 (e) D6 (f) D7 (g) D8. The time displayed in the graph is the respective end of that trial

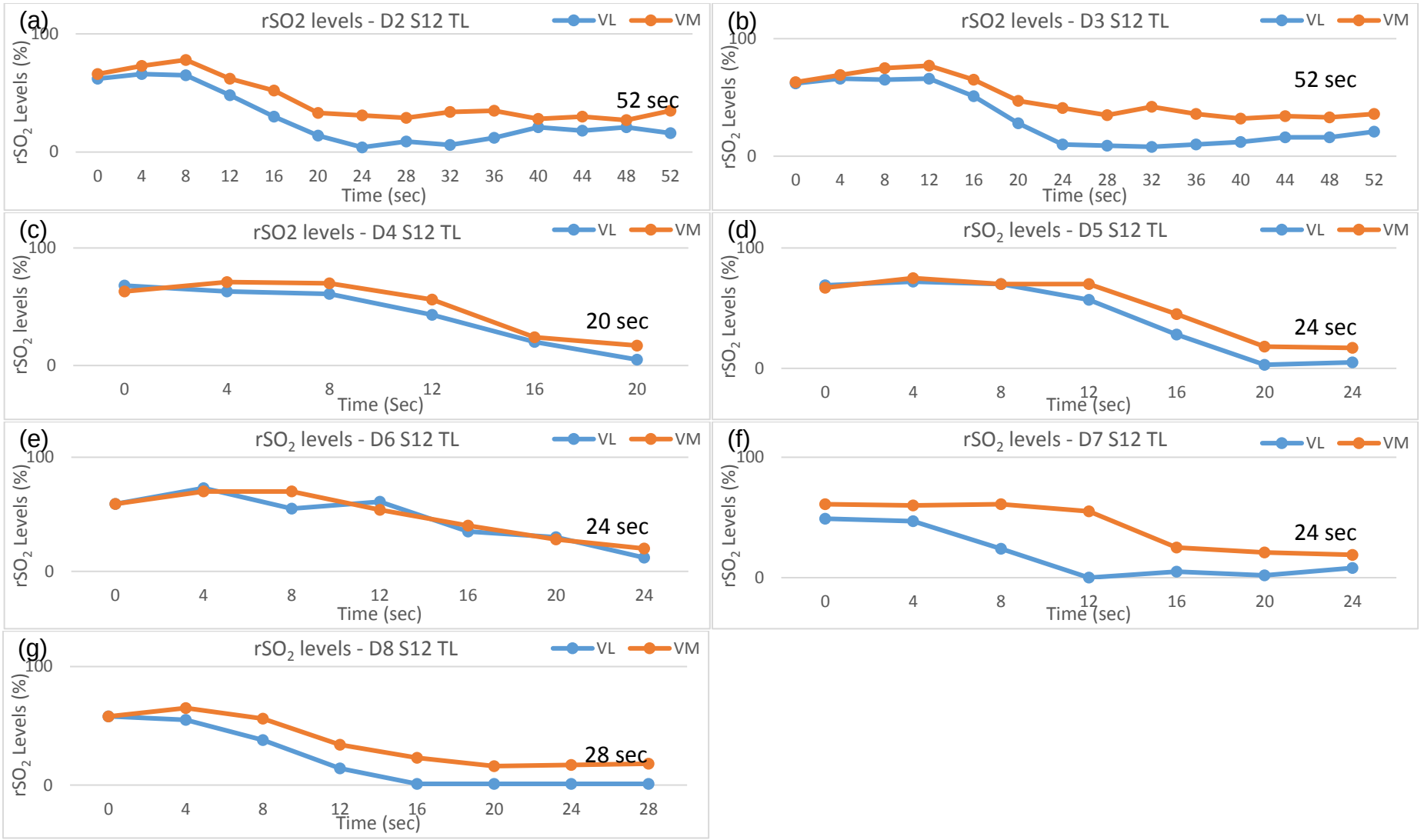

Figure F- 24: The rSO_2 levels treatment leg VM and VL during isotonic exercise from D2 to D8 in Subject 12. (a) D2 (b) D3 (c) D4 (d) D5 (e) D6 (f) D7 (g) D8. The time displayed in the graph is the respective end of that trial

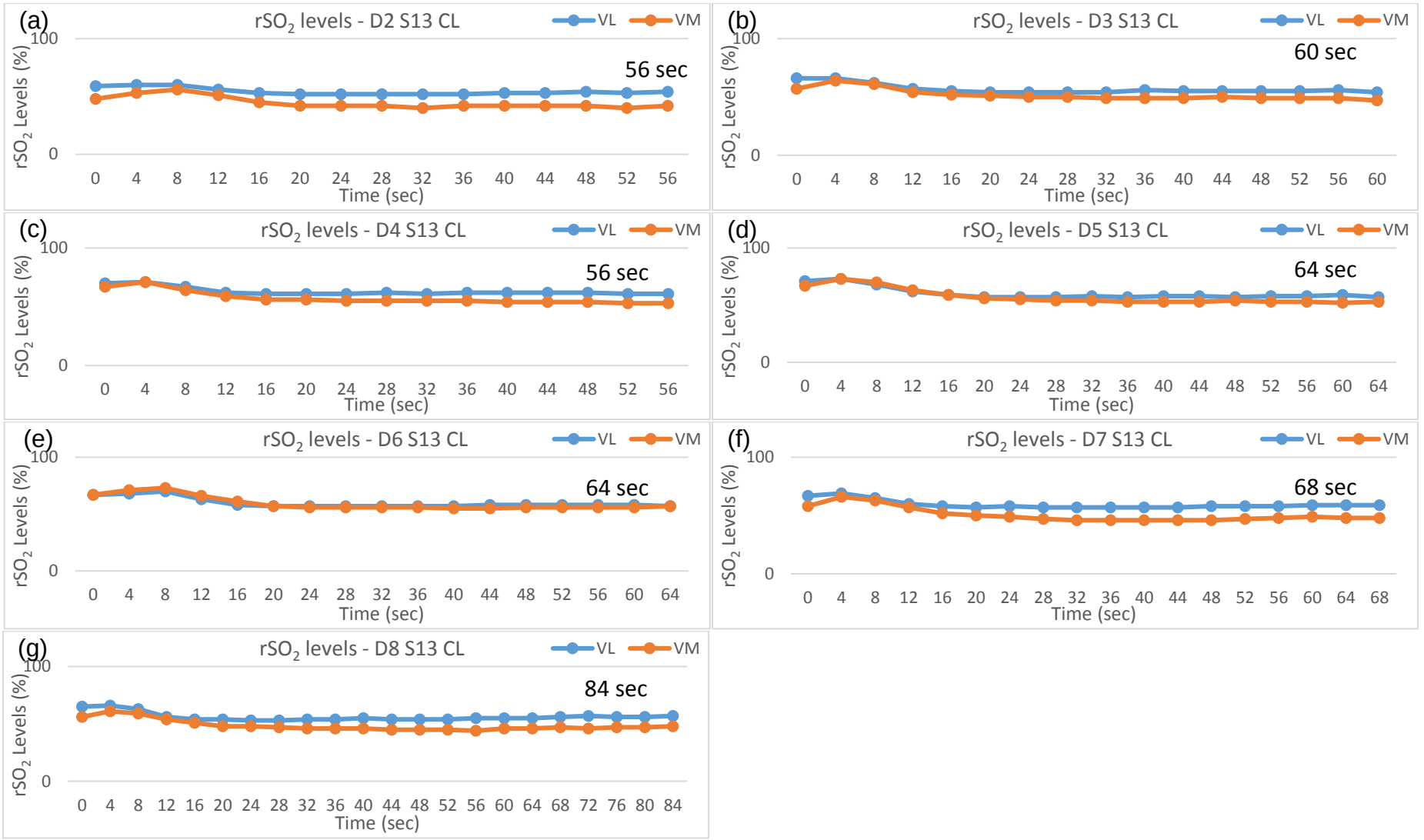

Figure F- 25: The rSO_2 levels control leg VM and VL during isotonic exercise from D2 to D8 in Subject 13. (a) D2 (b) D3 (c) D4 (d) D5 (e) D6 (f) D7 (g) D8. The time displayed in the graph is the respective end of that trial

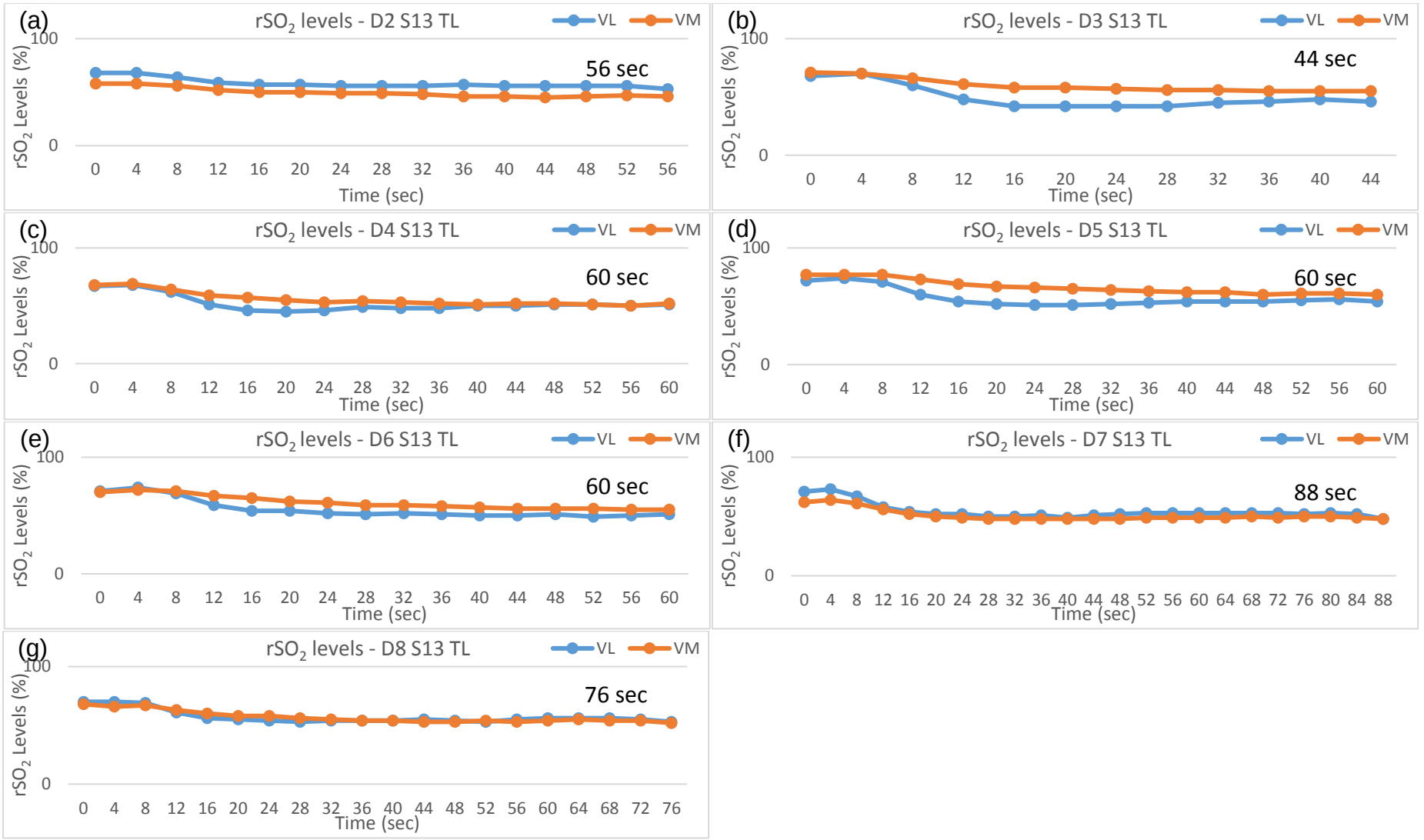

Figure F- 26: The rSO_2 levels treatment leg VM and VL during isotonic exercise from D2 to D8 in Subject 13. (a) D2 (b) D3 (c) D4 (d) D5 (e) D6 (f) D7 (g) D8. The time displayed in the graph is the respective end of that trial

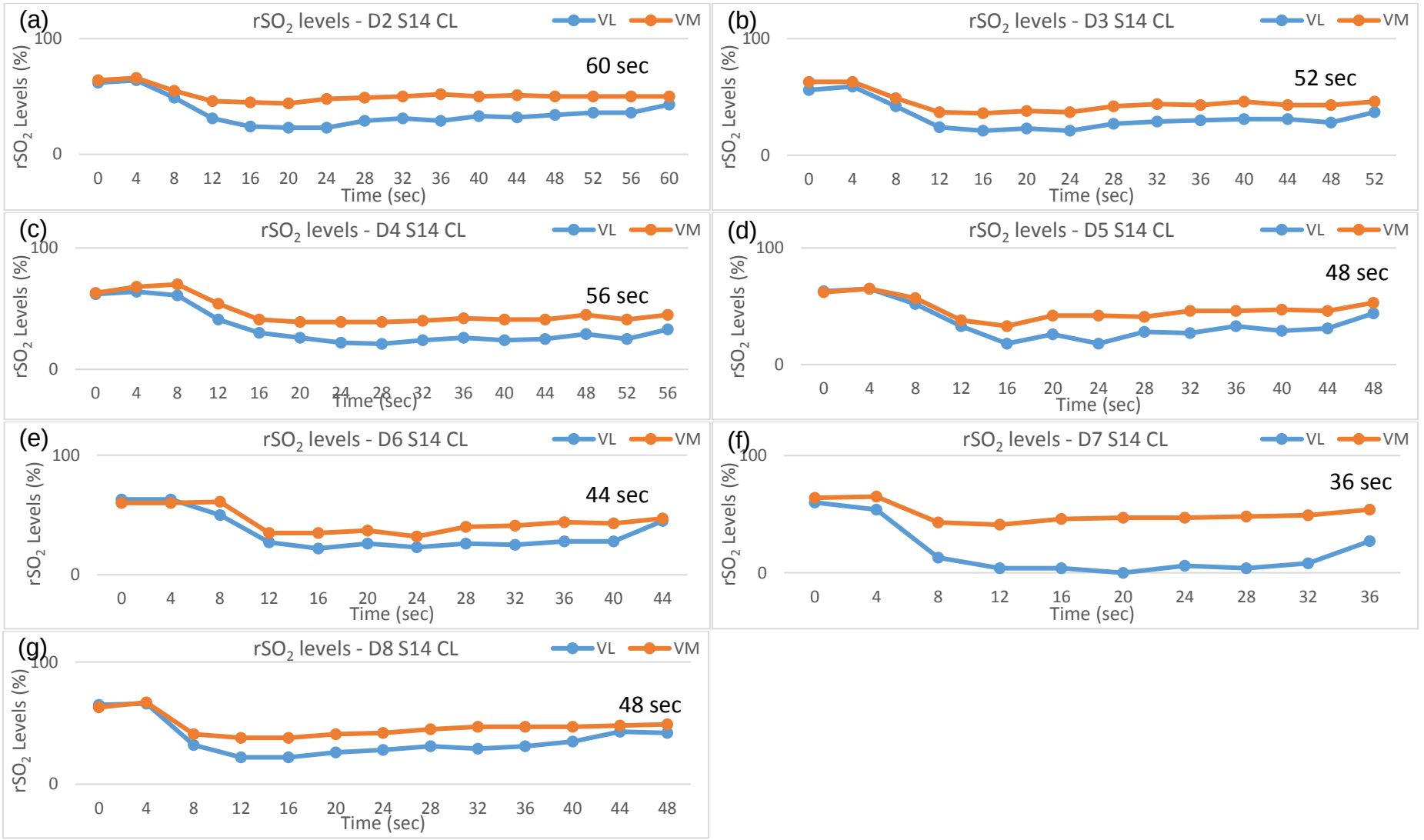

Figure F- 27: The rSO_2 levels control leg VM and VL during isotonic exercise from D2 to D8 in Subject 14. (a) D2 (b) D3 (c) D4 (d) D5 (e) D6 (f) D7 (g) D8. The time displayed in the graph is the respective end of that trial

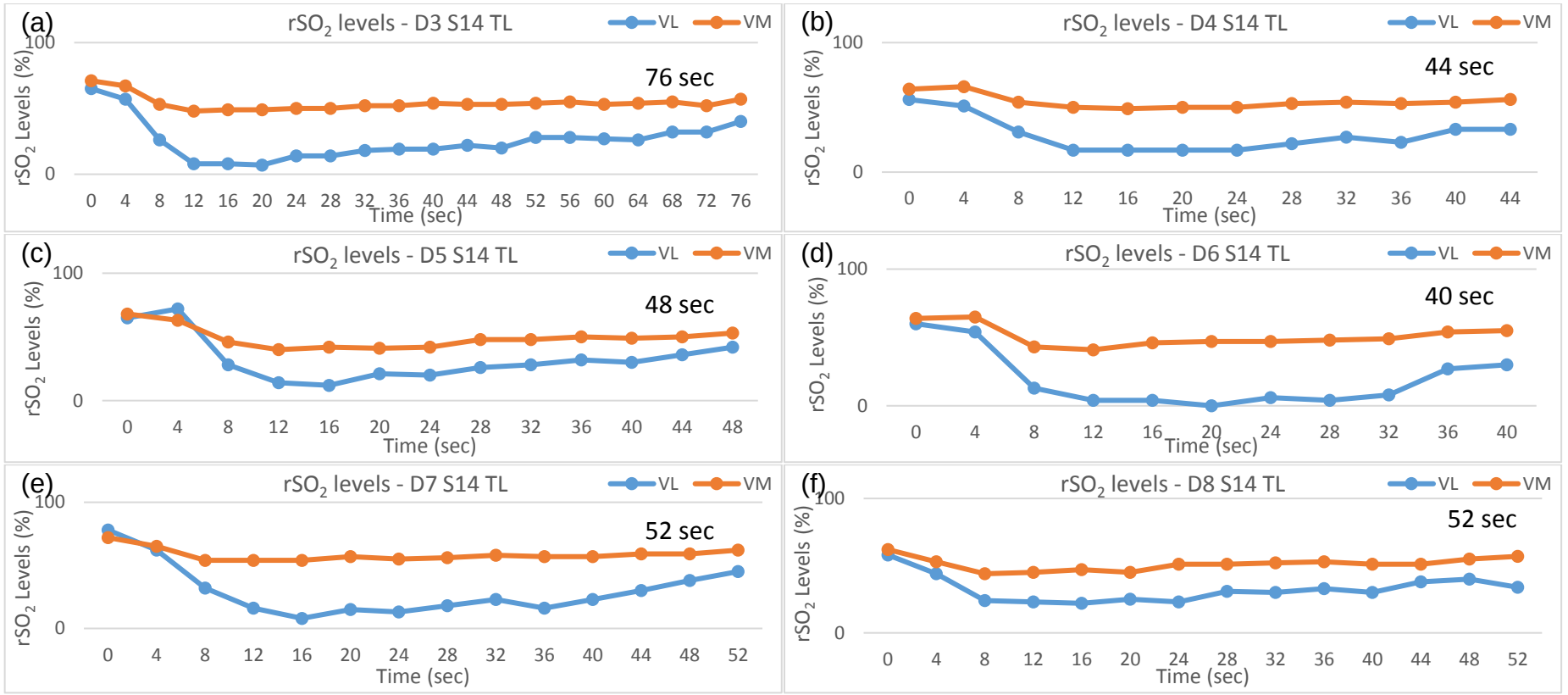

Figure F- 28: The rSO_2 levels treatment leg VM and VL during isotonic exercise from D3 to D8 in Subject 14. (a) D3 (b) D4 (c) D5 (d) D6 (e) D7 (f) D8. The time displayed in the graph is the respective end of that trial