Swedish Elite Swimmers Blood Glucose Levels During Recovery

-A Descriptive Study Using Continuous Glucose Monitoring Systems

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Abstract

Aim

The aim of this study is to form a descriptive picture of Swedish national elite (SNLE) swimmers blood glucose (BG) levels in relation to their nutritional intake.

- Do SNLE swimmers have BG level in a normal range of ≥3.9 mmol/L when measured during a six-day period?

- Is there a relationship between the SNLE swimmers blood glucose levels and how often or when they eat, and how they perceive their workout effort?

Method

Four test subjects, three females and one male, were recruited based on their competitive level, National Championship qualifying cut, geographical location, in Stockholm, and amount of swimming workouts completed weekly, seven on average. The test subjects wore a Continuous Glucose Monitor for a week and in addition a brief meal journal and perceived effort (ranking) of each workout was recorded. The data gathered was analyzed based on three main variables; *time spent LOW* (blood glucose level below 3.9mmol/L), *amount of meals,* and *ranking*.

Results

This study found that three out of four test subjects had occurrences of a LOW during the week. The test subjects spent on average 1.75 ±1.26 days with a LOW, the average time spent with a LOW per day was 37.3 ±29.7 minutes, the average amount during the whole week was 224 ±177 minutes, and the percent of the whole week spent with a LOW was 2.59 ±0.02%. In addition to this a correlation was found between *(total) time spent LOW* and *(total) amount of meals* with an R-value of 0.99, an R^2 of 0.979, and P-value of 0.044.

Conclusions

The results showed that three test subjects spent time with a LOW and indicates similar results should be found in the general population of SNLE swimmers, however, this is definitely in need of further research. The results also indicated that there is a relationship between the amount of meals ingested and the BG level over the full six-day period but not on a daily basis. A regression analysis between *(total) time spent LOW* and *(total) number of meals* showed correlations with statistical significance, however, there was too small of a data sample (N=4) to draw conclusions based from this. This study forms a descriptive picture of the situation, which could serve as a platform for further research in this field, and give a first glance at the possible potential use of CGM systems within the sports nutrition field.

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1 Introduction

The best swimmer of modern times, Michael Phelps, spoke in an interview with NBC about his training regimen. He stated that he trained almost every day for four years leading up to his most successful Olympic games in Beijing, 2008. (Flaherty 2016) Swimming has been known to consist of a very high training volume, often daily double swimming workouts as well as multiple “dry land” sessions (all training that is not in the pool). With this amount of exercise, recovery is crucial for the athlete to excel and reach full potential (Moore 2015, p. 299). Nutrition is becoming widely recognized as key to recovery in between exercise (ibid; Peterson et al. 2006, p. 282; Beck et al. 2015, p. 259). In an interview with the Washington Post Phelps stated eating 12,000 calories a day to cope with his workout routine (Flaherty 2016).

Swedish elite swimmers exercise on average seven to ten times a week, many of which starting early in the morning and finishing late in the evening. With a busy workout schedule comes the problem of eating enough. Research studies made on swimmers have found that they struggle to eat enough, particularly amid the youth (Hassapidou et al. 2002; Martínez et al. 2011). Among elite swimmers the specific problem is consuming enough carbohydrates (CHO) to accommodate a high level of performance (Provenza Paschoal & Silverio Amancio 2004; Farajian et al. 2004; Petersen et al. 2006). The study by Farajian et al. (2004, p. 583) showed that swimmers consume excessive amounts of fat and protein while an insufficient amount of CHO. An insufficient intake of CHO can slow the athletes recovery from the damage of exercise due to the increased oxidative stress it puts on the body (Farajian et al. 2004, p. 583) Furthermore, an insufficient CHO ingestion has proven to decrease muscle glycogen storage, in turn resulting in chronic muscular fatigue (Costill et al. 1988, p. 253).

Leading up to the 2016 Rio Olympics the Swedish National team swimmers were administered tests to ensure their nutritional intake was adequate to perform at the top level. They used a Continuous Glucose Monitoring (CGM) system to monitor their blood glucose (BG) levels. This is a system that uses a sensor on the lower abdomen to measure the interstitial fluid’s glucose level continuously over a seven-day period (Matuleviciene et al. 2014). The CGM allowed the Swedish National team swimmers to form an apprehension of their blood glucose levels between workouts. The tests concluded that some athletes had BG levels below a recommended level (< 3.9mmol/L). In follow up tests, after adjusting their diets, they were able to hold blood glucose levels at a normal level. According to their test leader[1], this put them in a better position to recover for the coming workouts.

Normal fasting BG, euglycemia, ranges between 3.9-6.1 mmol/L, while normal postprandial BG is below 10 mmol/L although healthy people rarely have values above 7.8 mmol/L. Values outside of the normal range are referred to as hypoglycemic (<3.9 mmol/L) or hyperglycemic (>6.1 mmol/L fasting and >10.0 mmol/L postprandial). (Mayo Clinic 2015; WebMD 2015) According to the American Diabetes Association (2014; 2015) the factors that can affect the blood glucose level are; food, alcohol, physical activity, insulin, diabetes medicines, illness or infection, stress, pain, the hormone cycle, and dehydration. Only the first three of these are easily controllable for the national team members. However, in the tests they used diet alone as means to maintain their blood glucose levels.

The larger number of elite swimmers in Sweden have qualified for nationals, but have not been able to make the national team. For the purpose of this study they will be referred to as Swedish national level elite (SNLE) swimmers. Many young swimmers do not reach that desirable national team position while some fortunate few do. Staying away from illnesses and excess fatigue as well as being able to recover properly could potentially allow more swimmers to reach a national team spot. When the national team did the tests with the CGMs they discovered that many team members did in-fact have inadequate diets, but it is at present unknown if the situation is similar among SNLE swimmers.

1.1 Current Research

Managing an athlete’s nutritional intake is a balancing act between the amounts ingested (caloric), what is being ingested (nutrients, micronutrients), along with timing of ingestion (in relation to exercise) (Hausswirth & Mujika, 2013, p. 83). According to the Swedish Olympic Committee an athlete should consume about 1-1.5 grams of CHO plus 0.3 grams of protein per kilogram of bodyweight within minutes from exercise completion (Sveriges Olympiska Kommitté 2016, p.19). The recommendations from the Swedish Olympic Committee are

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[1] Stig Mattsson, Dietist SOK, telefonsamtal 2016-06-13

supported by several studies (Ivy et al. 1988; Ivy 2001; Levenhagen et al. 2001; Moore 2015; Rustad et al. 2016).

In a study by Ivy et al. (1988) they tested the effect of nutritional timing on the replenishment of muscle glycogen levels. Twelve cyclists were ordered to complete a 70-minute workout on an ergometer during two different occasions. One workout was immediately followed by the ingestion of a 25% CHO solution (2g/kg bodyweight) while the other one followed two hours of recovery before ingesting the same CHO solution. (Ivy et al. 1988, p. 1480-1481) This study highlights the importance of an immediate post exercise meal, because it concluded that the recovery process started sooner when the cyclist received the CHO solution immediately post exercise. The study also presented that when the athlete had a delayed nutritional intake they had a 45% lower muscle glycogen synthesis rate. This was explained to be due to the glucose resynthesizing process being at its highest when ingesting CHO a few minutes in comparison to two hours post exercise. (Ivy et al. 1988, p. 1484) Newer studies also agrees with this (Levenhagen et a. 2001, p. 989; Stephens et al. 2007, p. 1114; Rustad et al. 2016, p. 17) further clarifying that the athlete who perfects their nutritional intake and timing will have a better chance at improving their performance during the following workouts and to adjust to the physical strain that daily multiple workouts have on the body (Moore 2015, p. 299).

In a review article by Ivy (2001) the reasoning behind the analysis that the timing of the CHO ingestion is key to muscle glycogen recovery is further deepened. After a bout of exercise the body has a protective mechanism to prevent hypoglycemia from developing, which can affect the muscle glycogen synthesis process (Ivy 2001, p. 238). This is put in effect due to the body's enhanced ability to synthesize glycogen post exercise using other processes than insulin action, such as muscle contraction, to enable the glucose entering the cell. This inhibits the cells from replenishing their storage as quickly as they would with a higher insulin level that would arise from immediate CHO ingestion. (Ivy et al. 1988; Houmard et al. 1999, p. 1057; Levenhagen et al. 2001, p. 989)

Another study that looked at the effect of muscle glycogen on glucose-, lactate-, and amino acid metabolism found that a low pre workout muscle glycogen level caused protein degradation in the muscle. The tests were performed on eight male subjects by having them cycle on a ergometer first with only one leg and the day after with both at which time one leg had less muscle glycogen content than the other. The research concluded that the level of muscle glycogen going into a workout has a clear effect on the muscles metabolism during the workout and can to some extent have a catabolizing effect mainly on the protein levels of the muscles. Along with this, they also found that the leg that had less muscle glycogen going into the workout used 30% more blood glucose during the exercise than the other leg. (Blomstrand & Saltin 1999, p. 296)

In an early study made by Costill et al. (1988) on male swimmers it was found that swimmers experienced muscular fatigue when they had failed to ingest enough CHO and as a result had lower than normal muscle glycogen levels. Later research on the athlete in a CHO deprived state, showed that it can cause impairment to the performance level and an immunosuppression greater than that of the exercise itself (Costill et al. 1988; Gleeson et al. 1998; Gleeson et al. 2003; Bartlett et al. 2013). A study by Gleeson et al. (1998) investigated the effect of CHO intake on the plasma cortisol levels of twelve healthy sedentary male test subjects. The group was divided and put on either a high- or low CHO diet for three days and performed a cycling ergometer test before and after the diet (Gleeson et al. 1998, p. 50). The study found that training when only 5% of the total caloric intake was from CHO resulted in an increase in plasma cortisol during exercise and a more substantial fall in plasma glutamine in addition to an increased neutrophilia post exercise. Further specifying the fall in glutamine concentration, resulting from the low CHO diet, as the greatest suppressor to the immune system putting the athlete at extra risk for infections (Gleeson et al. 1998, p. 57).

To the author's knowledge there is only one study that has looked at healthy athletes using the CGM system. This study put CGM systems on ten subelite athletes that exercised more than six hours during a six-day period (Thomas et al. 2016, p. 1336). Thomas et al. (2016, p. 1339) found their test subjects in general had no problems keeping their BG over the hypoglycemic range. Only one of their test subjects had BG levels below 4 mmol/L, and this person was also the only one to consume less CHO than recommended (Thomas et al. 2016, p. 1338). Instead the study found four out of ten test subjects had 70% of their BG levels over 6 mmol/L, excluding the postprandial values within two hours of a meal (Thomas et al. 2016, p. 1339). Furthermore suggesting that their test subjects consumed too much CHO to keep a normal BG level.

Other than hypoglycemia being related to the muscle glycogen recovery process, blood glucose levels below 3.6 mmol/L are correlated to cognitive dysfunction. Hypoglycemia causes a decline in cerebral glucose uptake, which affects the central nervous system (CNS). (Amiel 1998, pp. 713-719) The hypoglycemic effect on athletic performance is primarily evident during exercise where it lowers the average force production during muscle contraction, this is explained to be due to the decreased activation signals from the CNS (Nybo 2002, p. 593).

There is little research conducted in the chosen field of blood glucose management in relation to nutritional intake for healthy individuals. Some studies have concluded a relationship between the timing of post exercise intake and the body's ability to recover and rebuild the muscle glycogen stores (Ivy et al. 1988; Rustad et al. 2016, p. 17; Levenhagen et a. 2001, p. 989). Other studies have found a relationship between a low CHO diet and immunosuppression or lower muscle contraction ability (Costill et al. 1988; Amiel 1998; Gleeson et al. 1998; Nybo 2002; Gleeson et al. 2003; Bartlett et al. 2013). From both instances we can conclude that the cause is an inadequate dietary intake and that if an athlete has a low blood glucose prior to or post exercise it could have a negative effect on performance, thus hypoglycemia is something an athlete should avoid.

Continuous glucose monitoring systems are new to diabetics and even newer to the athletic society, but are currently being used by several national teams in Sweden. Even though the test method is already being used for healthy athletes, its only been used for research in one study thus far (Thomas et al. 2016), which indicates that the system needs more research to prove its effectiveness. The possibility to combine the CGM system with other testing methods that are already performed in the Sports Nutrition field could deepen the knowledge of how nutrition affects athletes' recovery and performance. Also, if the BG level could serve as an indicator of when athletes need to change their diets, it would be a method more personal than basing dietary advice off of a generic chart such as the one given by SOK today (Sveriges Olympiska Kommitté 2016, p.19). Due to the fact that this testing system has not been studied on nondiabetics, this study will serve as an investigative descriptive one. In addition to the aim of this study it could also give us a hint at the value (or lack of) of this technology for further studies.

1.2 Aim and Questions of Focus

The aim of this study is to form a descriptive picture of Swedish national level elite swimmers blood glucose levels in relation to their nutritional intake.

Questions of focus:

- Do SNLE swimmers have a BG level in a normal range of ≥3.9 mmol/L when measured during a six-day period?
- Is there a relationship between the SNLE swimmers blood glucose levels and how often or when they eat, and how they perceive their workout?

2 Method

2.1 Test Subjects

To execute this study four SNLE swimmers between the age of 19 and 25 years old (21.75 ±2.5 years) were recruited to partake in the tests. The recruited test subjects weighed 67 ±5.7 kg, were 172.3 ±5.9cm tall, and consisted of three females and one man (table 1). They were recruited based on a few reasons including geography, competitive level, and amount of workouts weekly. The test subjects live in the same city as the test leader, hold at least one national championship qualifying cut, and participate in at least seven workouts during an average workout week. They also swim in the top group for their club teams and are without injuries or medical conditions.

To determine that the test subjects did not have any unknown diseases affecting their BG level, they were told to take two fasting BG tests during the week. The test subjects administrated the fasting BG tests themselves before their first meal on two separate days. The average of these two values is recorded in table 1. Due to the test subjects fasting BG at 5.2 ±0.4 mmol/L, with normal fasting BG at 3.9-6.1 mmol/L, they were concluded healthy in this regard.

Table 1 – General information about the test subjects

Test subject	Sex	Age	Weight (kg)	Length (cm)	Fasting BG (mmol/L)
1	F	21	63	169	4,7
2	F	22	63	169	5,3
3	F	25	67	170	5,05
4	M	19	75	181	5,6

The test subjects received a full disclosure of the nature of the study and what was required from them after which they had time to ask questions. The test subjects were informed that they were partaking in the study voluntarily and could terminate their participation whenever they wished. After this information was shared they received an informed consent form that they signed (appendix 2). For the anonymity of the test subjects they are referred to as TS1 through TS4 (table 1).

2.2 Test Equipment

The equipment used in this study are Dexcom Continous Glucose Monitors (CGM), the G4 Platinum model, and Accu-Check Mobile glucose meters. The CGM system contains a receiver, transmitter, and sensor. The sensor and transmitter are placed into the test subjects subcutaneous fat on the lower abdomen using an applicator that comes with the sensor. The sensor measures the interstitial fluid glucose level every five minutes (Matuleviciene et al. 2014). It has to be in a range of seven meters from the receiver in order to transmit, resulting in that the blood glucose was not recorded from their swimming workouts (other than a few instances when they were in range during the workout). Because the system transmits intermittently every five minutes there might also be a gap of the same time from when the test subject exits the water and the system finds connection again.

The CGM G4 Platinum system has been tested in four separate clinical studies to determine its accuracy using the Mean Absolute Relative Difference (MARD). The MARD, a calculation that measures the average disparity between the sensor and the reference value, is estimated to be between 10-13.9%. (Damiano et al. 2013; Baile, Chang & Christiansen 2013; Matuleviciene et al. 2014; Kropoff et al. 2015) The Accu-Check Mobile, used to calibrate the CGM, has an accuracy level in accordance with the International Institute for Standardization by following their set of standards for blood glucose meters called DIN EN ISO 15197. This means that the meters measures with 98-100% accuracy within +/-15 mg/dl for BG levels <100mg/dl (13.9 mmol/L). (Freckman et al. 2012)

At the start of the testing period the test leader applied the sensor and the transmitter on the test subjects lower abdomen. After the sensor and transmitter were applied, the system needed calibration following a two-hour connection time, for the rest of the test period calibrations were needed every twelve hours. Calibration was at all times performed by the test subject using the Accu-Check Mobile glucose meter, after being taught and given instructions of the process by the test leader (appendix 3). The test subjects were asked to do a fasting blood glucose test twice during the week to make sure they had a normal fasting blood glucose (3,9-6,1 mmol/L), all test subjects had normal levels (table 1).

2.3 Additional Data Gathering

In addition to the CGM, the test subjects' nutrition was monitored through a brief meal journal. They wrote down what kind of meal they ate, breakfast, lunch, dinner, snack, drink or fruit, and described loosely what it consisted of such as; porridge, pasta with tomato sauce, potatoes and fish etc. The test subjects also recorded at what time they were eating each meal or snack. For the analysis, the meals were recorded if they consisted of an estimated amount of 15g of CHO or more, thus, small snacks such as a single serving of fruit was not recorded as a meal.

Finally the test subjects also wrote down the hours for their workouts along with a ranking of their "perception of training effort" post exercise. They wrote down the number that matched their perception in accordance with a ranking system used in the study by Costill et al. (1988, p. 250). The ranking system was used to gauge their level of fatigue and to spot a relation between that and their total time in minutes with a *BG below 3.9 mmol/L* (LOW). This ranking system is designed to be less impacted by the intensity level of the workout, which is why it was used for this study.

Table 2 - Ranking system of *Perception of Training Effort* used in the study

Perception of Training Effort	
Very easy, felt good during all parts of the workout	4
Neither hard nor easy, felt good during some parts of the workout	3
Somewhat difficult feeling a little heavy or sluggish	2
Very difficult, feeling very heavy and have trouble keeping my usual pace for interval sets	1

2.4 Data Analyses

No test subjects started their test week on the same day of the week, however, the data that have been analyzed are the six days not including the start- or finish day for all test subjects. All test subjects normally have seven swimming workouts per week, for the six days that were analyzed they completed between four to five swimming workouts each, all had dry land workouts in addition to the swimming workouts (table 3). The lesser amount of swimming workouts could be due to that they all participated in the Swedish National Championship a couple of weeks prior to the test week and were during off-season.

Table 3 – Showing number of workouts and minutes of workout for the full six-day period

Test subject	Number of workouts (swim+dry land)	Minutes of workout
1	5+2	615
2	5+1	565
3	4+2	630
4	5+3	885

The data from the CGMs were extracted using a program called Dexcom Studio and the raw data was transferred from there to excel. The raw data (the BG value per every five minutes) was analyzed using the programs SPSS (24th edition) along with Microsoft Office Excel (2011). The data was first collected in tables showing the collected results from each variable, these are presented by single day, total amounts, and average amounts, the averages are presented ± standard deviation.

An average of 1620 ±18 BG values were gathered from the test subjects during the six days that was analyzed. The Linear Regression Analyses, to determine the correlation between the variables; *Time spent LOW, Number of meals,* and *Ranking,* was made in SPSS while the other analyses were made in Excel. In the Linear Regression Analyses the variable *Time spent LOW* was always put as the dependent variable and compared against the other variables in two different analyses. The Pearson Correlation analysis was used to determine the correlation between the variables and a P-value > 0.05 was determined statistically significant. The data from these analyses was used to make graphs in Excel. The variables are presented in graphs using Excel.

The raw data from the CGM was used along with a meal-, training-, and ranking journal to create graphs representing a single day during the test week. In these graphs the test subjects days with the most time spent with a LOW (*worst day)* is depicted, along with TS1s second *worst day* because she did not have a workout during her *worst day* (*worst day* with a workout). The *worst day* analysis was used to show a picture of how the BG behaves over a full day when they had occurrences of a LOW. In this analysis the test subjects BG levels were analyzed during awake time and compared with the time of their meal and workout during that day. Therefor, these graphs depict the days from 05:00 in the morning until 00.00 at night.

3. Results

3.1 The Test Week in Numbers

Three out of four test subjects had occurrences of a LOW during the test week. The test subjects spent on average 1.75 ±1.26 days with occurrences of a LOW. Also among all test subjects the average daily time spent with a LOW was 37.3 ±29.7 minutes, the average amount during the whole week was 224 ±177 minutes, and the percent of the whole week was 2.59 ±2,1%. One of the four test subjects (TS1) came down with a cold just one day into the test week, due to which she was not able to train for a full five days. TS1 kept the sensor on for an extra week and the data used for the analysis came from that second week.

The longest time spent in LOW during the same day was by TS1 on day one, which included no workouts, this test subject also had the largest total time spent with a LOW (430 minutes) during the six days that were analyzed. TS1 had three days with occurrences of a LOW, the same as TS2, one of the days that TS1 spent with occurrences of a LOW was a no workout day (day 1). TS4 had two days with occurrences of a LOW one of which was during a no workout day (yellow colored boxes = no workout). The meal journal showed that this test subject had consumed six beers the night before this no-workout-day (day 4) with a LOW. TS3 spent no time with a LOW and was also the only one to have three days without a workout. Three test subjects had double workout days during the test period (green colored boxes = double workout day), one of them had a LOW during such a day (TS1). All the test subjects had at least one morning workout during the week that started no later than 08:00 (red number = a day with a morning workout). (table 4)

Table 4 – Time that each swimmer spent with a LOW (yellow = no workout / green = double workout / red = morning workout)

Time (min) spent with a LOW										
Test subject	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Total**	**Mean**	**Days LOW**	**Percent of total time spent LOW**
1	390	0	0	5	0	**35**	430	71,7 ±156,5	2	4,98%
2	**0**	65	5	**190**	0	0	260	43,3 ±75,3	3	3,01%
3	**0**	**0**	0	0	0	**0**	0	0	0	0,00%
4	140	**0**	**0**	65	0	0	205	34,2 ±58,0	2	2,37%
Average TS	132,5	16,3	1,3	65,0	0	8,8	223,8	37,3 ±52,5	1,75	2,59%

The range of the test subjects blood glucose level over the six-day period was between 2.66 mmol/L and 9.71 mmol/L. TS1 who also spent the most time with a LOW had the lowest BG value and TS3 who did not spend any time with a LOW had the highest BG value. TS4 had the highest average BG level at 6.02 ±0.95 mmol/L, while TS1 had the lowest average BG level at 5.33 ±0.89 mmol/L. All test subjects spent most time with a BG level under 6.97 mmol/L and over 4.44 mmol/L. (table 5)

Table 5 – Test subjects range of BG level in mmol/L

Test subject	**Lowest BG**	**Highest BG**	**Mean BG**
1	2,66	8,27	5,33 ±0,89
2	2,89	8,71	5,67 ±0,94
3	4,05	9,71	5,86 ±1,01
4	3,33	9,43	6,02 ±0,95

The two swimmers (TS1 and TS2) that had the most minutes of LOW were also those who ate the least amount of meals during the week, with two or four meals less than the other test subjects. The average amount of meals ingested daily during the six days was 5.8 ±0.3 meals and for the full six days 34.5 ±1.9 meals. The meals that have been accounted for are those with an estimated CHO content of more than 15 grams, thus single servings of fruit were not recorded as a meal. TS3 ate as many meals on average per day (6) as TS4, TS3 spent no time LOW while TS4 did. (table 6)

Table 6 – Number of meals with more than 15g of CHO content per day (yellow = no workout / green = double workout / red = morning workout)

Number of meals (>15g KH)									
Test subject	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Total**	**Mean**	**Total time spent LOW**
1	4	5	6	6	5	**6**	32	5,3 ±0,8	430
2	**6**	6	6	**6**	6	4	34	5,7 ±0,8	260
3	**7**	**6**	6	6	5	6	36	6 ±0,6	0
4	6	**8**	**6**	5	6	5	36	6 ±1,1	205
Average TS	5,8	6,3	6	5,8	5,5	5,3	34,5	5,8 ±0,4	223,8

Each swimming workout was ranked according to a table called *Perception of Training Effort*. The average test subject ranked 2.4 ±0.9 points. TS1 and TS2, who spent the most time with a LOW, were also those that ranked their workouts the lowest with average 1.3 ±0.8 and 2 ±1.0 respectively. (table 7)

Table 7 – Compilation of swimmers ranking of each swimming workout (yellow = no workout / green = double workout / red = morning workout)

Ranking								
Test subject	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Mean**	**Total time spent LOW**
1		2	1	2		**3**	1,3 ±0,8	430
2	**2**	3	1	**3**		1	2 ±1,0	260
3	**3**	**2**				4	3 ±1,0	0
4	3	**2,5**	**4**		4		3,2 ±0,8	205
Average TS	3,7	3	2	2,5	4	2,7	2,4 ±0,7	223,8

3.2 Regression Analyses

The regression analysis between *(per day) time spent LOW* and *(per day) number of meals* found low positive correlation with an R-value of 0.356, R^2-value of 0.127, and P-value of 0.049 (table 8). This analysis used data from each day for both variables, thus resulting in 24 cases per variable (N=24) (figure 1). The correlation of *(total) time spent LOW* and *(total) number of meals* over the full six-day period was close to perfect with an R-value of 0.99, an R^2 of 0.979, and P-value of 0.044 (table 8). This analysis consisted of a data case of four cases per variable (N=4). (figure 2)

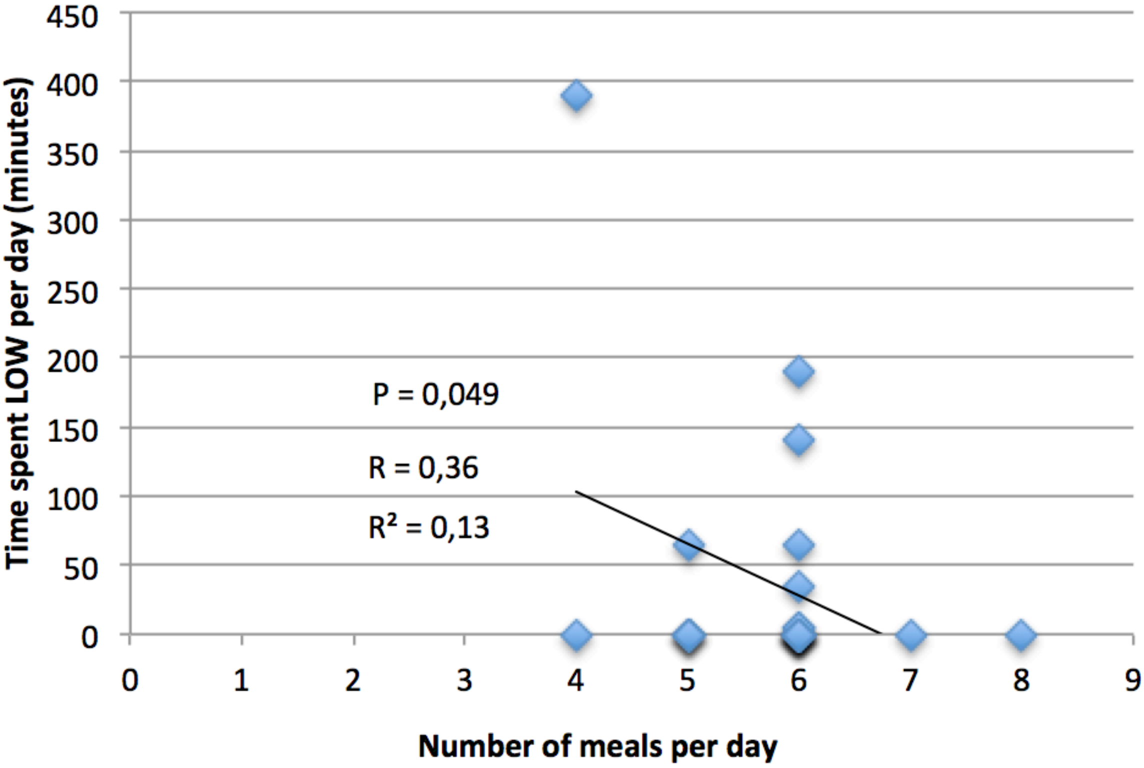

Figure 1 –The Linear Regression Analysis of *(per day) time spent LOW* and *number of meals*

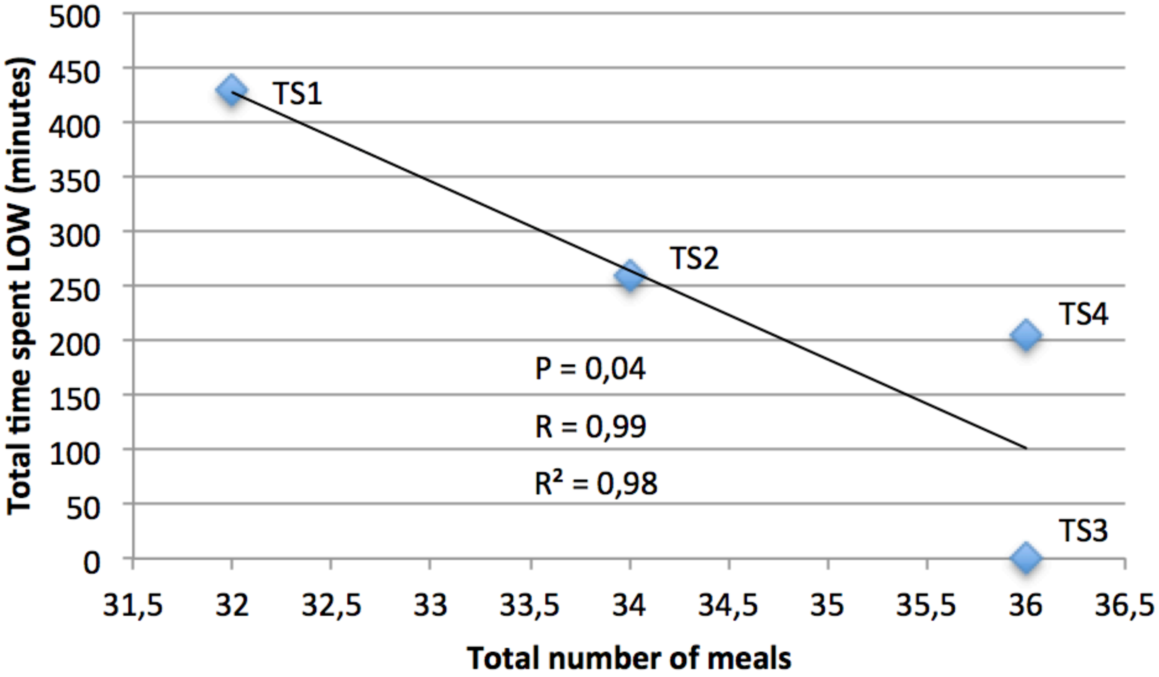

Figure 2 - The Linear Regression Analysis of *(total) time spent LOW* and *number of meal*

Table 8 – The regression analyses results of all variables

Regression analysis	P	R	R^2
Total time spent low vs number of meals	0,044	0,990	0,979
Total time spent LOW vs average ranking	0,106	0,827	0,684
Per day time spent LOW vs number of meals	0,049	0,356	0,127
Per day time spent LOW vs ranking	0,050	0,200	0,040

Comparing *(per day) time spent LOW* to *(per day) ranking* of the workout resulted in no correlation (R = 0.200, R^2 = 0.040, P = 0.050) (table 8). This analysis had a data of 15 cases per variable (N = 15), which includes data for *time spent LOW* and *ranking* for the days that the test subjects had a workout (figure 3). The *(total) time spent LOW* and *(average) ranking* analysis resulted in a positive correlation (R = 0.827, R^2 = 0.684) (figure 4). This analysis showed a less than acceptable probability (P>0.05) with the P-value at 0.106 indicating that another variable might be responsible for the satisfactory correlation. (table 8)

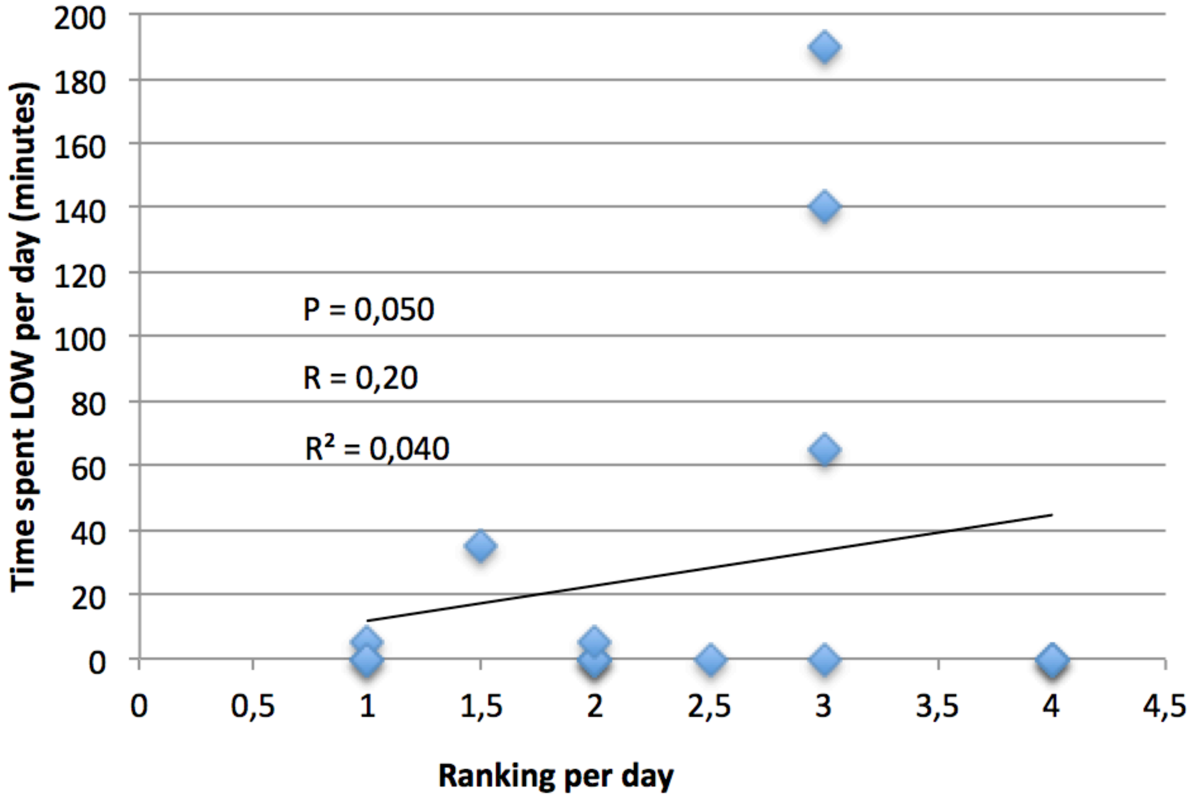

Figure 3 –The Linear Regression Analysis of *(per day) time spent LOW* and *ranking*

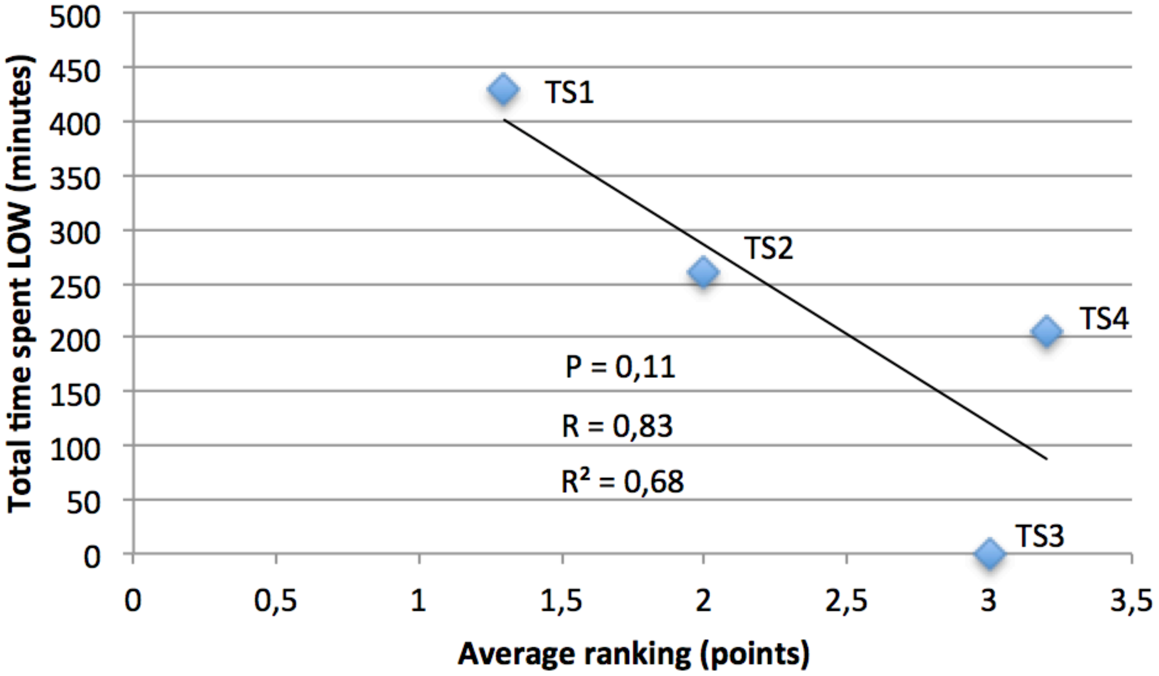

Figure 4 - The Linear Regression Analysis of *(total) time spent LOW* and *average ranking*

3.3 Example of the Worst Day

Three of the swimmers spent two or more days with a LOW, while one swimmer had no days with LOW. The three swimmers *worst days*, the day where they spent the most time with a LOW while also having one or more workouts, are depicted in figure five, seven, and eight. TS1 spent most time with a LOW during a day with no workout (day 1), therefor, this day is also presented (figure 6). TS1 had a LOW during the dry land workout and directly afterwards (figure 5), as well as during a day without any workouts (figure 6). TS2 was low right after the exercise (figure 7) while TS4 had a LOW in the morning, before any meal or exercise (figure 8). TS1 had a LOW for only a short time post exercise (day 6) and TS4 for about one hour and 30 minutes in the morning (day 1) while TS2 had a LOW on and off from right after her morning workout at eight until seven at night (day 4).

TS1s was the only one who had double workouts during a day with occurrences of a LOW (day 6), and ate two more meals than the other test subjects on this day totaling at eight meals. During day six TS1s BG remained in the lower range of 4.36 ±0.42mmol/L until after lunch from when she kept a BG of 5.23 ±0.51mmol/L. (figure 5) TS1 was also the only test subject with the most time spent with a LOW during a day without exercise (day 1) (figure 6). During this day she spent 390 minutes with a LOW and consumed five meals. TS1s meal and workout diary shows that she had no workout on the day before either.

Noteworthy in the graph for TS2 (figure 7) was that three of the meals resulted in a sharp increase in BG level and followed quickly by sharp decline. After meal two through five during there was an increase of 1.8 ±0.2mmol/L in 37 ±3min, measured from the lowest point before the increase to the peak. The peak followed by a drop of 1.7 ±0.6mmol/L in 33 ±10min measuring from the peak until the point when the BG stopped decreasing.

TS4 had no LOW in proximity to his workout that day, his meal and workout diary for the week shows that he had a three-hour workout the night before (between 16:00-19:00). TS4s BG rises right before his first meal of the day and then stays in a normal range of 6.32 ±0.83 for the rest of the day (08:50-00:00). (figure 8)

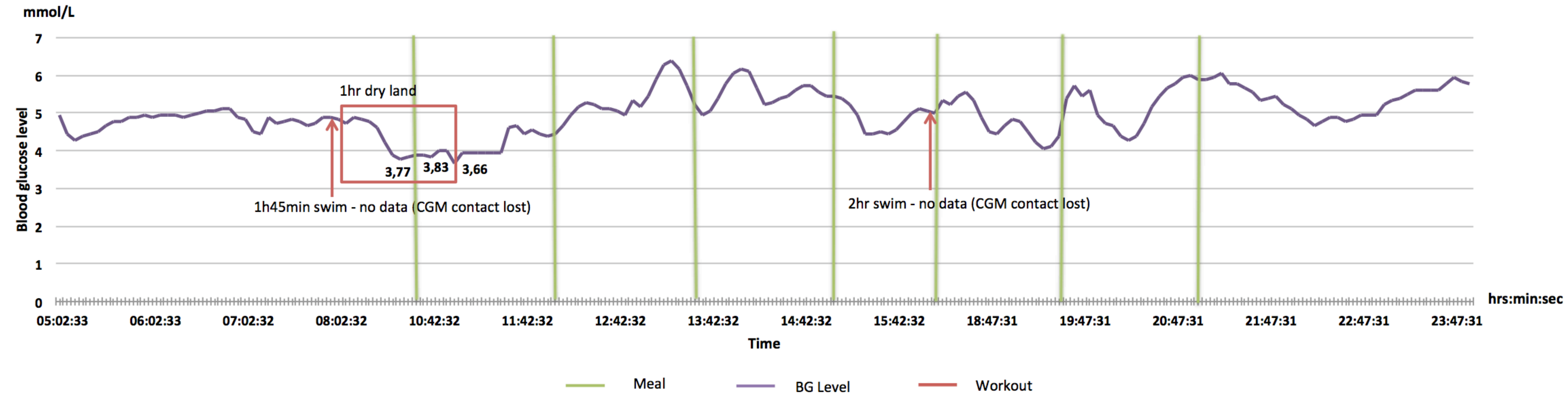

Figure 5 – TS1s Worst day with a workout (day 6) between 05:00-00:00

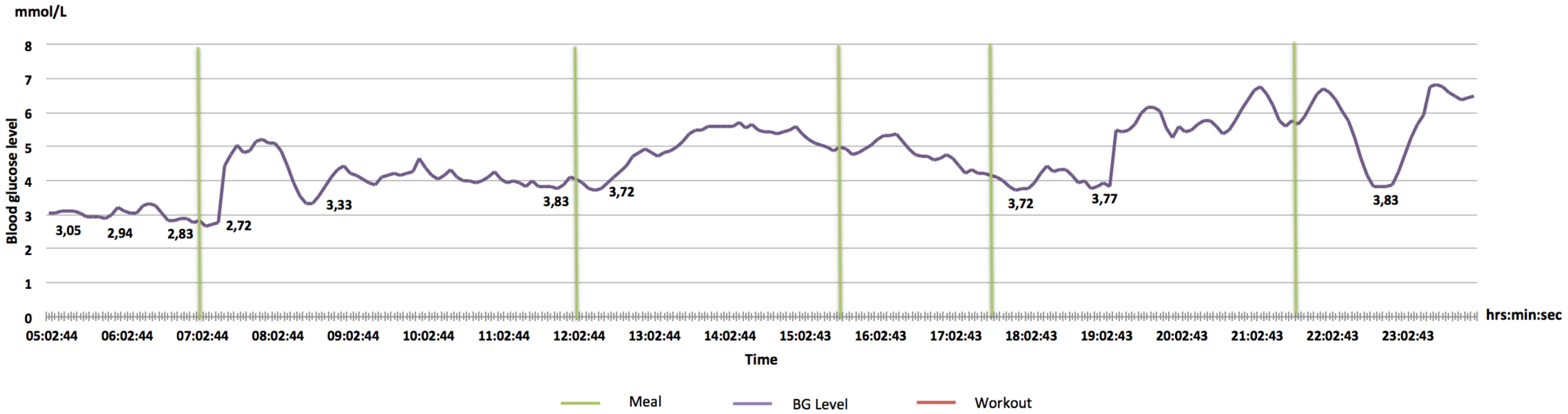

Figure 6 – TS1s Worst day without a workout (day 1) between 05:00-00:00

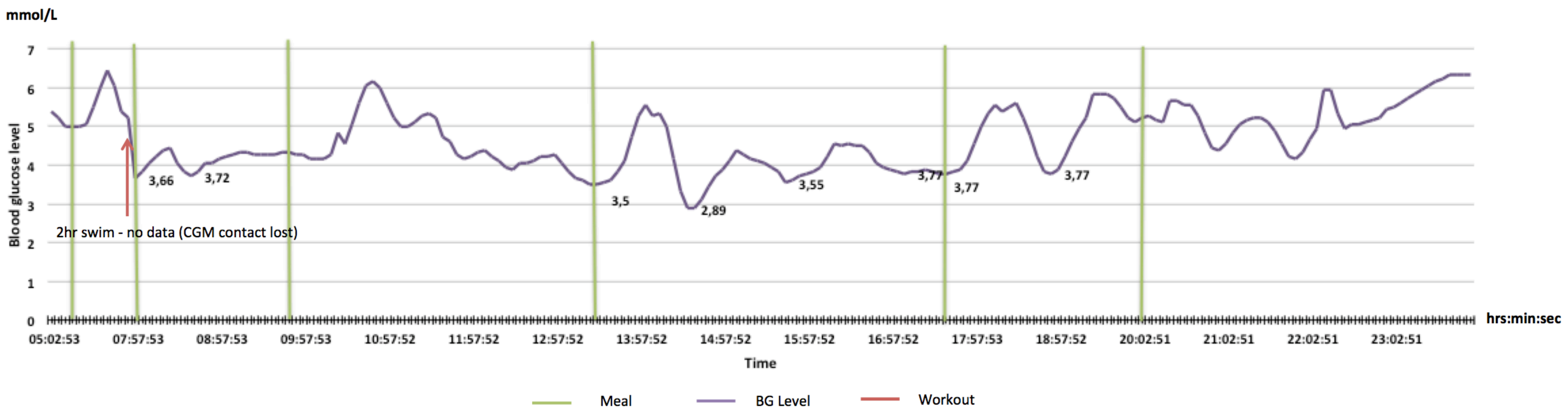

Figure 7 – TS2s Worst day (day 4) between 05:00-00:00

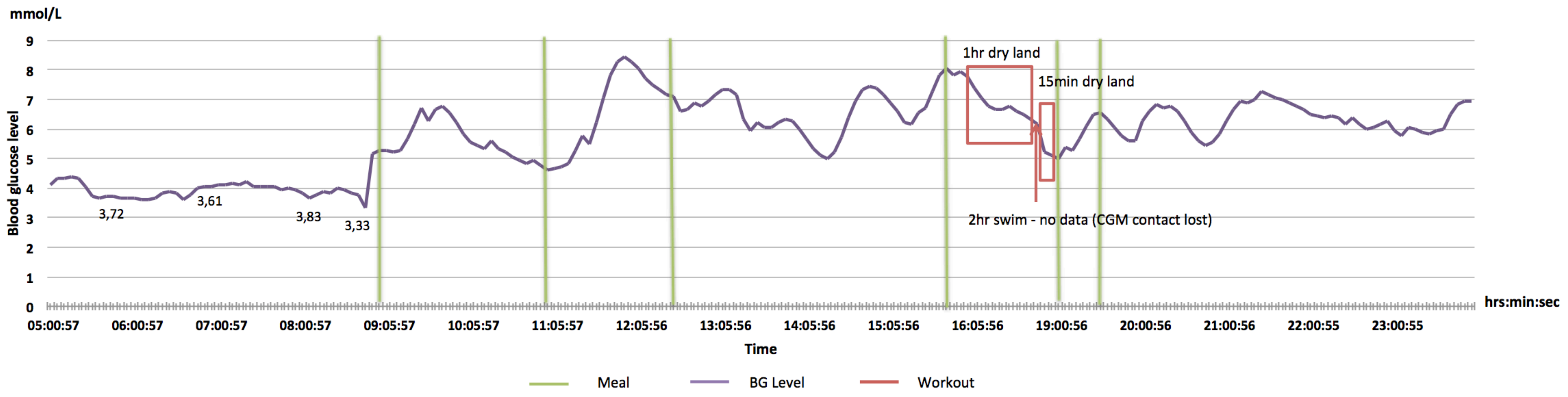

Figure 8 – TS4s Worst day (day 1) between 05:00-00:00

4. Discussion

The aim of the present study was to form a descriptive picture of SNLE swimmers blood glucose levels in relation to their nutritional intake by asking a couple of questions.

Do SNLE swimmers have a BG level in a normal range of ≥3.9 mmol/L when measured during a six-day period?

This study found that SNLE swimmers do not always have BG levels in the normal range of ≥ 3.9 mmol/L (Mayo Clinic 2015). In fact, the test subjects spent on average 224 ±177 minutes below the normal range during the six-day test period. The large spread of the data (SD = 177) is due to TS3 who did not spend any time with a LOW. This finding leads to a few follow up questions, such as why the test subjects had a LOW and what implications this may have on their recovery and performance? Some of the possible answers for the first question can be found in prior studies, while the second question remains to be unanswered and only speculated on due to it being out of the scope of the present study.

Two of the major causes of hypoglycemia are diet and exercise. The study by Farajian et al. (2004, p. 583) found that elite athletes often consume an inadequate amount of CHO. It is very likely that some of the test subjects' LOWs could have been prevented through adequate CHO intake or less exercise. With the latter not being a choice for elite athletes, a well-managed CHO intake is key to them maintaining a normal BG level. The result of this study indicates that the test subjects lacking nutrition over the whole period might have caused them to spend time with a LOW. Since TS3 consumed the same amount of meals as TS4, but TS4 still spent time with a LOW and TS3 did not, the CHO content of each meal might be more important than the number of meals.

In addition, several studies have shown that inadequate recovery nutrition can have an direct impact on the athletes' replenishment of muscle glycogen stores (Ivy et al. 1988; Levenhagen et al. 2001; Rustad et al. 2016). An inadequate recovery meal post exercise may be a reason to three out of four test subjects having several occurrences of a LOW, both during recovery and also during exercise. As can be seen in figures five through eight, TS2 and TS4 both consumed a meal immediately post exercise, while TS1 consumed a meal in between swimming and dryland, as well as within an hour post exercise. Thus, the timing of the meal should not implicate their recovery, although possibly for TS1 who ate closer to one hour post exercise. What definitely could have effected their recovery during these days is the CHO content of these meals.

According to the only other study on healthy athletes using the CGM system, the CHO content of the athletes' diet had strong effect on their BG levels. There was one test subject that consumed less than the recommended amount, which was the only one to have BG levels below 4 mmol/L. (Thomas et al. 2016, pp. 1338-1339) Still discussing the *worst day* analysis, it seems that TS1 and TS4 consumed enough CHO because they kept a euglycemic value after their meal, while TS2 had an unsteady BG level for the most part of her day following the morning workout, suggesting that she probably did not eat enough CHO post exercise. Based on the conclusions done by Thomas et al. (ibid) it would have been interesting to see the total CHO intake of the test subjects in this study to be able to conclude if they consumed a less than recommended amount, and if this was the reason for the LOWs. At the same time, in the means and time frame of the current study a complete nutritional diary from the test subjects was not possible. In addition to this, it might have been problematic to get test subjects to adhere to a six to seven day weighed diet record. In accordance with the purpose of this study, this type of meal tracking sufficed to form a descriptive picture of the relationship between BG level and diet.

Other than in the means of proper recovery, several studies have also found that adequate nutritional intake and nutritional timing has a direct impact on the replenishment of muscle glycogen levels post exercise (Ivy et al. 1988, p. 1484; Levenhagen et al. 2001, p. 989; Stephens et al. 2007, p. 1114; Rustad et al. 2016, p. 17). Furthermore, the study by Blomstrand and Saltin (1999, p. 293) found that when a muscle has a low glycogen storage pre exercise it will use 30% more blood glucose than a muscle with a filled up glycogen storage. Indicating that if an athlete is not managing their nutrition well enough to restore glycogen levels between workouts, they are more likely to use additional blood glucose during exercise. This is reinforcing what is already known, that muscle glycogen levels and BG levels are related. TS1 had a LOW during the dry land workout on day six (figure 5) and TS2 had a LOW immediately after exercise on day four. These LOWs could be direct results of an inadequate nutrition during the recovery from their previous workout that prevented their muscle glycogen levels to replenish properly and caused them to use more glucose during their workout.

According to several studies, there is a direct correlation between hypoglycemic values and the athlete's ability to hold the wanted intensity level (Amiel 1998, pp 713-719; Nybo 2002, p. 593). According to this some of the athletes (TS1 and TS2) in this study should have had implications on their workouts due to them having occurrences of a LOW during the exercise. At the same time according to the ranking on these days, TS1 ranked a one while TS2 ranked a three, showing that the BG level probably did not effect their Perceived Effort Ranking. Yet, the test subjects ranking is a subjective measure of their perceived performance, if their performance level would have been measured objectively the results may have differed. Such objective measurements could include having them perform a distance for time after each workout, or, in addition to their own ranking, their coaches could have ranked their workout effort as well.

The study by Ivy et al (1988, p. 1484) explained that it is likely that this alternative uptake of glucose by the cell, other than from insulin action, is to remain for an unknown period of time possibly extending up to 15 hours if the athlete has not consumed enough CHO post exercise. This could explain TS4s LOW in the morning before any exercise or meal, since he had a three-hour workout the night before. However, the reason behind the amount of time spent with a LOW during TS1s *worst day* without a workout remains a question. This study does not take in to consideration the other activities that the test subjects participates in, maybe that is the reason for TS1s time spent with a LOW. Another reason could be that her diet was so poor that even though she did not have any workout on that day or the day before she was not consuming enough CHO to maintain euglycemia.

TS1 was the test subject that spent the most time with a LOW, she was the only test subject that had to delay her test week due to an infection. Several studies have shown that an inadequate CHO intake among athletes can cause an increased immunosuppression (Costill et al. 1988; Gleeson et al. 1998; Gleeson et al. 2003; Bartlett et al. 2013). One of the most prominent effects on the BG level is diet, which makes it possible that TS1s infection could have been caused partly due to having LOWs during the week before the study began. This is highly speculative, because her BG level during the week prior to the study is unknown. In addition, so is the direct correlation between *time spent with a LOW* and *risk to develop an* *infection*. At the same time, TS1 did spend considerable amount of time with a LOW during the test week, suggesting this could be a constant pattern for her.

Other than TS1s first day with no workout and a long time spent with a LOW, TS4 was the only other test subject with occurrences of a LOW on a day without a workout (day 4 = 65 minutes). According to the American Diabetes Association (2014) alcohol affects the BG level for up to 24 hours after drinking during which it can cause hypoglycemia. In addition to not eating enough to counteract the effect of the alcohol, the alcohol itself should be the reason why TS4 had a LOW in the morning of day four.

Previous studies have found that the BG level affects the athletes' performance level during exercise by decreasing the muscles ability to produce force (Amiel 1998, pp 713-719; Nybo 2002, p. 593). Two of the test subjects had occurrences of a LOW during exercise (TS1 and TS2) and if the body's' ability to produce force during exercise is impaired then maybe it could effect the progress gain from that workout. If athletes spend considerable amount of workouts with a LOW then maybe, this could have a long term effect on performance.

However, it has yet to be proven if a hypoglycemic event could affect the athletes' performance when it occurs during recovery between workouts. What we know is that when hypoglycemia occurs the body does not have enough glucose at hand to keep the BG in euglycemia, which does not occur at rest or during exercise with enough stored glycogen in the liver and during exercise with enough stored glycogen in the muscles. If an athlete remains with a LOW during an extensive period of time during recovery, such as for TS1 on day one, TS2 on day four, and TS4 on day one, it indicates that their glycogen stores are not full. At the same time, if the blood glucose is kept at a normal range it does not mean that the athlete has full glycogen stores.

Furthermore, looking at why TS3 never spent any time with a LOW, it could be assumed that she managed her post exercise meal well and was able to replenish her glycogen stores between each exercise (Ivy et al. 1988; Levenhagen et al. 2001; Rustad et al. 2016). However, it could also mean that her muscle glycogen levels were high enough to keep euglycemia but still not full. For example, TS3 could have had unsatisfactory muscle glycogen levels during recovery, but still have a normal blood glucose level due to the body's protective system that prevents hypoglycemia by decreasing the amount of insulin released or secrete more glucose from the liver (Ivy 2001, p. 238). TS3 ate as many meals per day (average = 6) as TS4, while TS4 participated in more minutes of exercise (885 minutes) compared to TS3 (630 minutes). Observed from this, TS4 should need to eat more meals than TS3 to refrain from a LOW, however that conclusion is only speculative because the CHO amounts of their meals are unknown.

In addition to that TS3 could have kept a better dietary regime resulting in no LOWs, she also had the most days out of all test subjects without a workout (3 days). TS3 was moreover the only one to have four swimming workouts compared to the others who had five swimming workouts, the implication of this cannot be determined because this study has not looked at the affects of different type of exercises on the BG level. At the same time, even if TS3 had fewer swimming workouts, she had the same amount of total workouts (6) as TS2 and more total minutes of workout than both TS1 and TS2, thus, fewer swimming workouts should not have effected her results. Nevertheless, spending three days without any workouts could very well have affected her to not spend any time with a LOW.

Unknown is also the intensity level of the workouts, it may very well be the case that TS3 had less intensive workouts during the test period compared to the other test subjects. It is known that the body needs more glucose while the body is performing a higher intensity workout than during a low intensity workout with the same length (in time) of the workout. Therefore intensity, especially to explain TS3's results, would have been great to measure and is certainly something to be considered in further studies within this field.

Moreover, all test subjects participated in fewer swimming workouts than their normal amount weekly, which was told to be seven workouts or more. This could have resulted in that all test subjects spent less time with a LOW than they would have during a normal workout week in the season. It would be interesting to compare the test week from this study to a week during high season to see if they would spend more time with a LOW when they have more workouts. This would not necessarily be the case, another reason could be that the athletes did not think as much about their diet during this test week because they were off season, and that during a high season week they would be more thoughtful about their diet.

The study by Thomas et al. (2016) found that there is a larger problem with high BG levels than low ones among subelite athletes. At the same time, the test subjects for that study spent only six hours or more of workout during the six-day test period (Thomas et al. 2016, p. 1336), while the test subjects of the present study spent more than nine hours of workout during the same time period. Even though the total workout amounts differ between this study and the one by Thomas et al. (ibid) the results of the latter could still help explain why there were not more occurrences of a LOW during the week. However, the study by Thomas et al. (ibid) also contained a thorough meal journal depicting exact CHO content. If the present study had used a thorough meal journal, maybe it would have shown that TS3 consumed more CHO than recommended and that this was why she never had a LOW.

Is there a relationship between the SNLE swimmers blood glucose levels and how often they eat and how they perceive their workout?

This study found no significant correlations between the variables that were analyzed to answer this question. There were regression analyses with high R-values indicating a correlation does exist, however, these had a low sample size (N=4) and should therefor not be considered significant. At the same time, the aim of this study was to form a descriptive picture and with that at mind the correlations might serve as a platform for future research in this field.

One of the regression analyses with a high R-value but low data sample was between *(total) time spent LOW* and *(total) number of meals*. This analysis resulted in a strong positive correlation ($R = 0.99$, $R^2 = 0.979$, $P = 0.044$) suggesting that the swimmer who eats more meals (>15g of CHO content) during a period of six days will have a LOW for less time during that same period. The same kind of analysis made between the *time spent LOW (per day)* and *number of meals (per day)* did not have a strong correlation ($R = 0.356$, $R^2 = 0.127$, $P = 0.049$). This analysis had a larger, but nevertheless modest, data sample (N = 24) and a good significance ($P < 0.05$). Based from this the amount of meals consumed per day cannot determine *time spent LOW (per day)*, however, the analysis between *(total) time spent LOW* and *(total) number of meals* indicates of a pattern that the one who eats fewer meals is running a higher risk to have a LOW.

At the same time, this analysis contained a very low data size (N=4) and the results showed that both TS3 and TS4 consumed the same amount of meals during the week while having spent different amount of minutes with a LOW (TS3=0, TS4=205). If the meals could have been categorized in terms of CHO content, such as 15-25g, 25-50g, 50-75g, and so on, the results may have differed. Maybe TS3 who did not spend any time with a LOW ate considerably more CHO per meal than TS4 and that is why they consumed the same amount of meals and had different times spent with a LOW.

In addition to this, making analyses with a variable such as *(per day) amount of meals* is quite difficult since it is a rather fixed variable with more or less six meals per day for all athletes (average = 5.8 ±0.3 meals per day). Looking at when the meal was ingested in relation to the BG curve, visible in the *worst day* analysis, makes it easier to see a connection between the meal and BG level. For example, during TS2s *worst day* she consumed several meals that caused a rapid increase followed by a rapid decrease to a LOW. For this particular example it would have been interesting to know exactly the amounts and contents of the meals to make further conclusions of why she kept getting a LOW during the whole day. Nevertheless, the CGM gives the athlete an opportunity to analyze their dietary intake.

The regression analysis between *(total) time spent LOW* and *ranking* found a strong correlation ($R = 0.827$, $R^2 = 0.684$, $P = 0.106$), however, the P-value suggested that the significance of this result is unsatisfactory ($P > 0.05$) and the sample size was too small to base a conclusion from ($N=4$). Supporting the results of the regression analysis, which suggests there are other variables that could explain the strong correlation, are examples from the *worst day* analysis. During two of the test subjects *worst days* with a workout (TS1 and TS2), they had LOWs close to the exercise when one scored low (1) and the other one high (3). TS4 also scored high (3) for his *worst day,* although TS4s occurrences of a LOW that day were not close to exercise. This result was also supported by the analysis of *time spent LOW (per day)* and *ranking (per day)*, which showed poor correlation ($R = 0.200$, $R^2 = 0.040$, $P = 0.050$). This analysis had a modest data sample ($N = 15$) but a good significance ($P < 0.05$). All of the results are fortifying that perceived effort according to the ranking system used in this study does not determine the time spent with a LOW.

It is highly possible that the *ranking* system was too subjective and that it is why there was no correlation between that and the *time spent low.* If there had been an objective measure of effort, maybe the results would have differed. Perhaps some of the test subjects are used to training with a LOW? If such was the case, they could have scored higher on the ranking scale, even though their training effort was not as high as it could have been during euglycemic conditions. It is possible that adding an objective measure of effort to the study would have shown the BG levels effect on effort during exercise.

Other reasons to be critical to the results of the analysis between *time spent LOW* and *number of meals* or *ranking* could be that it is possible the amount of time spent with a LOW is affected by the intensity of the workout, a variable which was not measured in this study. In terms of the relationship between *time spent LOW* and *number of meals*, intensity should not play an important part. Certainly, intensity of the workout affects the total caloric output and this impacts the amount of food needed to satisfy the test subjects caloric need. However, the test subjects of this study are elite athletes that cannot change their workouts in regard to their nutritional intake, instead the nutritional intake should always be the variable needed to change relative to the intensity of the workout.

Concerning the other analysis, between *time spent LOW* and *ranking,* intensity could very well have had an effect on the BG level that was accounted for in this study. The ranking system was designed not to address the intensity level only the effort, no matter the intensity. However, it being a subjective measure, the intensity level could have still played a role in the ranking. Therefor, it could also have been beneficial to record the intensity levels of each workout to see if some test subjects had more easy workouts than others. It is possible that if some test subjects had more intense workouts during the week, it could have been a reason to them spending more time with a LOW. The intensity level could have been easily measured by measuring the test subjects pulse during the whole workout, which would have resulted in an objective intensity level for each workout. Though, due to the financial- and time restraint, this was not possible to execute for this study.

4.1 Strengths and Weaknesses

The Dexcom CGM G4 Platinum sensor is widely tested on its first week (Damiano et al. 2013; Baile, Chang & Christiansen 2013; Matuleviciene et al. 2014; Kropoff et al. 2015), although it is also possible to restart it for a second week. This was utilized in the present study to receive usable results from TS1 after she got an infection one day after applying the sensor. TS1 kept the sensor on for an extra week and the data that was analyzed came from that second week. The studies that have tested the validity of the CGM G4 Platinum system have not tested if there is a lower MARD or Accuracy over Time during the second week (ibid). The Swedish retailers claim that the one-week recommendation is a precaution directed towards the people with type one diabetes that are the main users of the product. Strengthening the validity of the data from TS1s test week (the second week of wearing the sensor) is that the fasting blood glucose recorded by the CGM remained in the same range (4,5-5,5 mmol/L) during the second week as during the first week. The data from TS1 is in this study considered equally reliable to the results from the other three test subjects.

Ideally, TS1 would have received a new sensor for the second week, however, the cost for the sensors is too high. The high cost of the CGM systems further impedes this study from making substantial conclusions due to it forcing the low number of test subjects. The equipment used to perform these tests cost over 10 000 Swedish crowns per system. The receiver and transmitter were borrowed from the Swedish supplier, while the sensors had to be paid for by the author (850sek per sensor). A larger data sample, either from more test weeks or test subjects, or both could have lead to making more significant conclusions. It could also have made certain that the study could handle data loss. At the same time, the aim of this study was to form a descriptive picture of the current situation and this was possible in an efficient way by to the small test group, the CGM system and loosely based meal journal. While a sample size of ten subjects would have lead to the study being able to handle data loss, it is still not large enough to base general conclusions of the population that is being studied. To make such conclusions it would have certainly needed more than ten, possibly more than 30 test subjects also from different club teams around the country.

Another possible weakness that needs to be considered is the reliability of the CGM G4 Platinum system. The MARD for the CGM has an estimated range between 10 and 13.9% (Damiano et al. 2013; Baile, Chang & Christiansen 2013; Matuleviciene et al. 2014; Kropoff et al. 2015). Meaning that when the CGM shows 5 mmol/L it could be as much as 0.7mmol/L off the actual value if compared to the blood glucose in vivo. More significant to this study, while the CGM shows a normal reading (3.9-6.1 mmol/L) the test subject could as well have a LOW. This type of variance is acceptable for the main use of the system among people with diabetes, their BG values will for natural reasons have a wider range to begin with (ibid). Meanwhile, among healthy individuals, where the changes in BG are quite small to begin with, this level of disparity between CGM value and actual value may have a more substantial effect on the reliability of the data. Due to the MARD of the CGM systems, even if it is acceptable to the main users, some LOWs could have been missed implicating the results of this study.

The time of the workout has been taken into consideration when analyzing each individual's data, but is overlooked when comparing the test subjects. The time of day may have an impact on the BG level potentially due to its implications on sufficient nutrition pre and post exercise. If the workout is in the morning it could lead to insufficient pre exercise nutrition because the workout precedes a long fasting period. While, if the workout is late at night it could lead to insufficient post exercise meal because fasting occurs very shortly after exercise. However, out of eight morning workouts among the test subjects, only two followed with occurrences of a LOW, which was during TS1s day six and TS2s day four. Also, the test subject that had the most morning workouts (TS3) was the only one to not have any occurrences of a LOW. TS4 had a low in the morning following a night workout, suggesting the time of the workout resulted in him spending time with a LOW. In future studies looking to compare athletes in terms of their BG level, it could therefore be of importance for them to have the same workouts at the same time of day.

The distance the test subjects specialize in could have affected the results of the study due to that swimmers with different main racing events will train differently. For example, a distance swimmer tends to swim longer workouts in terms of distance while keeping a lower intensity level in relation to a sprinter. Thus, this potential weakness could have been decreased if there would have been a measure of intensity included in the test method, as was brought up in the discussion.

A last possible weakness to the study was that no information regarding the test subjects' life other than regarding swimming was taken account for, which could have impacted the BG level. Lets say one of the test subjects were a postman and the others were students, the postman partakes in more physical activity outside of swimming than the rest of the test subjects, physical activity being one of the main reasons to hypoglycemia. Thus, this variable should be included as a factor within future studies in this area.

4.2 Future Research

This study showed that three out of four swimmers spent at least 205 minutes each with a BG level considered as hypoglycemic (< 3.9 mmol/L). It would be interesting to see if the same was true within a larger sample size. It would also be interesting to study the effects of an intervention after the first week of test. This could be done with a larger sample size by having a test group and a control group. The test group would receive the intervention while the control group would not and then the differences would be analyzed. Such further studies could lead to a deeper knowledge in the efficacy of the CGM system.

Combining these types of tests with an objective measure of performance such as tracking an athletes' performance over time would allow us to find if there is a relationship between performance and blood glucose level over time. Today the relationship between BG level and performance is unknown, thus, further studies are needed to determine if there is a benefit for performance to look at the BG level. The tests that were done on the national team showed a benefit to the athletes that were tested, however, this is a benefit that has never been statistically proven or academically explained. If it could be statistically proven to be beneficial, there would be increments for more club teams to use this system in order for their athletes to improve their performance.

In further research it would also be interesting to see if the correlation that this study found between the variables *(total) time spent LOW* and *(total) amount of meals* would hold up with a larger amount of test subjects. Past research proves there is a strong correlation between nutritional timing post exercise and the glycogen storage (Ivy et al. 1988, p. 1484; Levenhagen et a. 2001, p. 989; Stephens et al. 2007, p. 1114; Rustad et al. 2016, p. 17), it would be interesting to see more of how this relates to the BG level. On this topic of diet, it would also be interesting to see if doing a complete nutritional diary would give more answers to why the test subjects did not have a LOW on some days but on other, or why TS3 did not have a LOW at all. Also, if the exact CHO content would have been measured they could have been compared to recommended amounts, such as the guidelines from SOK (Sveriges Olympiska Kommitté 2016, p.19). This could allow personalized dietary advice to athletes based of their BG levels.

The only study that has researched healthy subelite athletes using the CGM system focused mainly on the relationship between CHO intake and BG values over 6 mmol/L. This study only researched the potential connection between BG values below 3.9 mmol/L and diet or ranking. (Thomas et al. 2016) It would be interesting in future research to also look at if there is a relationship between higher BG values and the recovery time and performance of elite athletes. It seems athletes should be one of the few populations that need their BG level in homeostasis, due to the continuous strain they put on their bodies through multiple daily workouts in order to succeed. Seemingly, it should be substantial for them to not have values out of the normal range.

Future research using the CGM systems along with other tests such as measuring the pulse during exercise to determine intensity level, vein and arterious blood samples to actual BG level to the one presented in the CGM, and muscle biopsies to measure the muscle glycogen content during different times pre- and post exercise. The latter two have been used in previous studies regarding nutrition (Ivy et al. 1988; Houmard et al. 1999; Levenhagen et a. 2001; Stephens et al. 2007; Rustad et al. 2016) and could together with CGM testing increase our knowledge of how nutritional intake and exercise of elite athletes connects to the BG level.

5. Conclusion

Judging by the fact that BG monitoring is mainly studied within the diabetes field, it is surprising that the results showed that these test subjects, elite athletes, were in hypoglycemic BG range for a average of 37.3 ±29.7 minutes per day or 224 ±177 for the full six days, still including that TS3 did not have a LOW during the whole period. Previous studies have shown the implications of an inadequate diet, but how it affects the BG level is still a very new problem that needs more research. This study indicates a possible correlation between number of meals ingested and BG level when looking at it over a longer time period of six days, while also showing that in a group of four SNLE swimmers, three will have BG values below normal.

The results of this study have weaknesses due to its few test subjects and basic meal journal. However, this is a new field with a novel test method (CGM) that has only been used once before on healthy athletes. Therefore, the results of this study should primarily be used in accordance with the aim of the study, as forming a descriptive picture of the current situation, secondary as a platform for further research in this field, and lastly as a first glance to the potential of using CGM systems within the sports nutrition field.

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Appendixes

Appendix 1

Litteratursökning

Syfte och frågeställningar:

The aim of this study is to form a descriptive picture of Swedish national level elite swimmers blood glucose levels in relation to their nutritional intake.

- Do SNLE swimmers have a BG level in a normal range of ≥3.9 mmol/L when measured during a six-day period?
- Is there a relationship between the SNLE swimmers blood glucose levels and how often they eat and how they perceive their workout?

Vilka sökord har du använt?

blood glucose homeostasis for recovery

blood glucose and carbohydrate intake and post exercise

carbohydrate intake and post exercise

post exercise and carbohydrate intake and recovery

muscle glycogen resynthesis and recovery

blood glucose and recovery and athletes

hypoglycemia athletes recovery

blood glucose and athletes

fasting glucose

fasting glucose and athletes

fasting blood glucose AND normal range

fasting blood glucose AND normal range AND athletes

fasting plasma glucose AND elite athletes

glucose monitoring AND athletes

normal fasting blood glucose

blood glucose AND carbohydrate AND athletes AND post exercise

blood glucose AND low carbohydrate AND athletes AND post exercise

blood glucose AND immune system AND athletes

blood glucose AND nutrition AND athletes

blood glucose AND nutrition AND post exercise

questionnaire AND general condition AND post exercise

immune system AND post exercise nutrition
muscle glycogen AND resynthesis AND post exercise
muscle glycogen AND blood glucose AND recovery
nutrition AND swimmers
nutritional intake AND swimmers
continouos glucose monitoring
continouos glucose monitoring athletes
hypoglycemia post exercise effects
insulin sensitivity AND post exercise
post exercise insulin AND muscle contraction
euglycemia and athletes
hypoglycemia in healthy adults
hypoglycemia in healthy adults athletes
hypoglycemia in healthy individuals

Var har du sökt?

SPORTDiscus, PubMed och Google Scholar.

Sökningar som gav relevant resultat

SPORTDiscus:
blood glucose and athletes and recovery
blood glucose and athletes
muscle glycogen resynthesis and recovery
carbohydrate intake and post exercise
insulin sensitivity AND post exercise
post exercise insulin AND muscle contraction
immune system AND post exercise nutrition

PubMed:
hypoglycemia post exercise effects

Kommentarer

Det har tagit lång tid att hitta bra artiklar, de flesta artiklar hittades genom att använda innehållsförteckningarna i andra artiklar och olika review articles, få artiklar hittades genom orginal sökningarna som står listade ovan.

Appendix 2

Test subject information and informed consent form

C-uppsats

Författare: Joanna Olsson

Titel: Swimmers blood glucose levels in correlation to their nutritional intake

- A descriptive study using Continuous Glucose Monitoring systems

1. Bakgrund och syfte

Tidigare studier har visit att näringsintaget mellan träningspass är väldigt viktigt och har en direkt påverkan på idrottarens återhämtningsförmåga. Om näringsintaget är otillfredsställande är risken stor att blodglukosvärdet hamnar under det rekommenderade värdet på >3.9mmol/L. Vid blodglukos tester på det Svenska simlandslaget fann man ett mönster av för låga blodglukos värden på vissa simmare vid vissa tider på dygnet. Detta korrigerades genom att simmarna ändrade näringsintag i samband med träning. Syftet med denna studie är därför att forma en deskriptiv bild av Svenska elitsimmare på nationell nivås blodglukosvärden under återhämtningsperioden och hur dessa korrelerar med tid för näringsintag.

2. Förfrågan om deltagande

Du har blivit tillfrågad att vara med i denna studie på grund av din nivå som SM simmare och den klubben du tillhör.

3. Hur går studien till?

Som deltagare i studien innebär det att du kommer behöva bära en kontinuerlig blodglukos mätare (CGM) under en veckas tid samt testa blod glukos värdet i fingret två gånger per dag. Den kontinuerliga blodglukos mätaren förs in under huden vid ett tillfälle och sitter sedan kvar hela veckan, detta görs med hjälp av testledaren.

Testledaren kommer att finnas tillgänglig under hela veckan via telefon och vara närvarande vid 3 träningspass under veckan för att svara på frågor och se till att allt går bra.

Dina blodglukosvärden kommer efter veckan att analyseras för att bedöma hur ofta du ligger inom normalt spann >3.9mmol/L och hur ofta du ligger på för låga värden dvs. ≤3.9mmol/L samt vid vilka tidpunkter du gör detta i förhållande till träningspassen, dessa resultat kommer du att få tillgång till om du vill.

Utöver detta kommer du som testperson få notera vilka tider du äter under dygnet samt vilken sorts mål det är, dvs. frukost, lunch, middag eller mellanmål, samt värdera känslan efter träningspassen utefter en förbestämd skala.

4. Vilka är riskerna?

Det finns inga risker med studien, men det kan förekomma ett visst obehag i samband med placeringen av den kontinuerliga blodglukos mätaren samt blodglukos testerna i fingret. Testledaren kommer att gå igenom hur du på bästa sätt ska testa i fingret innan testveckan börjar.

5. Finns det några fördelar?

Fördelarna för dig att delta i denna studie är att du får reda på hur dina blodglukosvärden ser ut under en vanlig träningsvecka, samt hur tiden du äter i förhållande till träning tycks påverka dina värden.

6. Hantering av data och sekretess

Dina resultat kommer att behandlas så att inte obehöriga och din tränare kan ta del av dem, så länge du inte väljer att delge det själv. Du kommer att vara anonym i studien och benämnas som testperson 1, testperson 2 och så vidare.

7. Hur får jag information om studiens resultat?

Om du vill så kommer dina resultat att delas till dig och hela studien kommer att finnas tillgänglig till dig om du vill.

8. Frivillighet

Deltagandet i denna studie är helt frivilligt och du kan när som helst, utan förklaring, avbryta ditt deltagande. Detta medför dock att inga resultat från ditt deltagande kan användas i studien.

9. Ansvariga

Testledare
Namn: Joanna Olsson
Telefonnummer: 070-221 0557
Mail: joanna.olsson@student.gih.se

Handledare
Namn: Marcus Moberg
Mobil: 070 229 50 79
Mail: marcus.moberg@gih.se

Skola: Gymnastik och Idrottshögskolan, Stockholm

Informerat samtycke

-Jag bekräftar att jag fått denna skriftliga samt annan muntlig information om studien.
-Jag ger mitt samtycke till att delta i studien och vet att mitt deltagande är helt frivilligt.
-Jag är medveten om att jag när som helst och utan förklaring kan avsluta mitt deltagande.
-Jag tillåter att mina personuppgifter registreras enligt den information jag tagit del av och att insamlad data om mig förvaras och hanteras elektroniskt av studieansvariga.

………………………..	………………………..	………………………..
Datum	Testpersonens namnteckning	Namnförtydligande

…………………………………………………………………
Testpersonens födelsedatum (år, månad och dag)

………………………………	………………………………………………………..
Testpersonens mobil nummer	Testpersonens e-mail

Undertecknad har gått igenom och förklarat studiens syfte för ovanstående forskningsperson samt erhållit forskningspersonens samtycke. Forskningspersonen har även fått en kopia av forskningspersonsinformationen.

………………………..	………………………..	………………………..
Datum	Namnteckning	Namnförtydligande

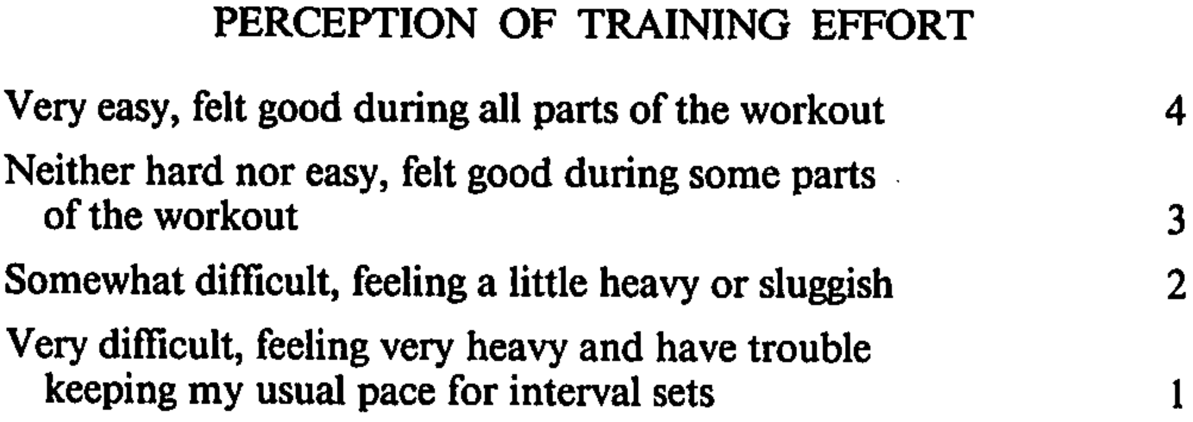
Appendix 3

Instructions for BG testing and CGM calibration

Instruktioner inför test med CGM

Generella instruktioner:

1. Kalibrera CGM var 12:e timme +/- ca 2h som mest/minst, hellre för tidigt.
2. Skriv ner kalibreringsvärde i ”kostregistrering + ranking av träningspass”.
3. Två gånger under veckan gör kalibreringen fastande (morgon).
4. Bär alltid med CGM, eller placera inom 7m från dig, förutom vid träning, efter träning kan det ta ca 5min innan du ser ett värde ovanför grafen igen.
5. Står det något annat än en siffra ovanför grafen (förutom precis efter träningspasset, eller då du råkat vara mer än 7m ifrån mottagaren) kontakta Joanna på 0702210557.
6. Notera tidpunkt för varje måltid och dryck annat än vatten och beskriv den, ex. Frukost: havregrynsgröt med mjölk och sylt, Lunch: Pasta med köttfärssås, Middag: Potatis och fisk, Snacks: choklad och lösgodis, Mellanmål: skinkmacka + juice, Dricka: två starköl, skriv in detta i dokumentet ”kostregistrering + ranking av träningspass”.
7. Ranka känslan efter varje träningspass utefter ”Perception of training effort” rankingsystem som du ser här nedan, skriv in i ”kostregistrering + ranking av träningspass”:



PERCEPTION OF TRAINING EFFORT

Very easy, felt good during all parts of the workout	4
Neither hard nor easy, felt good during some parts of the workout	3
Somewhat difficult, feeling a little heavy or sluggish	2
Very difficult, feeling very heavy and have trouble keeping my usual pace for interval sets	1

Instruktion för första kalibrering av CGM:

1. Efter sensorplacering behöver CGM ”vila” i 2h innan första kalibrering
2. Efter 2h sker första kalibrering då du gör på samma sätt som i instruktionerna nedan fast två gånger med ca 5-10min mellanrum.

Instruktioner för blodglukosmätning och CGM kalibrering:

1. Tvätta finger med alkowipe (välj alltid någon av de tre mittenfingrarna)
2. Öppna mätaren så att en ny testremsa kommer fram
3. Vrid nålpennan så att du får en oanvänd nål, stick sedan fingret på sidan (inte mitt på)

4. Tryck ut första droppen blod och ta bort med en papperstuss
5. Tryck ut en andra dropp blod och placera på testremsan
6. Vänta några sekunder på värdet
7. Mata in värdet i CGM genom att:
    a. Tryck på mittenknappen två gånger
    b. Gå in på Enter BG
    c. Mata in värdet du fick i blodsockermätaren
    d. Tryck på mittenknappen två gånger och vänta tills kalibrering är klar

Lite kort om Dexcom CGM:

Användarmanual:

http://www.dexcom.com/sites/dexcom.com/files/international/user_guides/LBL-011893_UsersGuide_G4PLATINUM_Swedish_mmol.pdf

Snabbfakta:

- Det är en räckvidd på 7 meter mellan sensor/sändare och mottagaren.
- Data skickas mellan sensor/sändare och mottagare vart 5e minut.
- Väldigt dyr så ta väl hand om den!

Dexcom G4 PLATINUM-mottagare

Dexcom G4 PLATINUM-sändare

Dexcom G4 PLATINUM-sensor