

LOW HAEMOGLOBIN MASS AND CORRELATION TO AEROBIC PERFORMANCE IN TYPE 1 DIABETES

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ABSTRACT

Blood oxygen carrying capacity and peripheral oxygen consumption, together with blood volume, play essential roles in determining aerobic capacity. In diabetes with chronic kidney disease anaemia is a common, and in early stages non-symptomatic, complication. Anaemia progress gradually and reduces oxygen delivery during exercise impairing aerobic capacity in diabetics. PURPOSE: 1) To study if type 1 diabetes patients (T1D) had anaemia or early signs of it in terms of low total haemoglobin mass (tHb-mass) or alternatively hypervolemia. 2) To study if the ratio of tHb-mass vs. maximal oxygen uptake (VO_{2max}) is similar in T1D and in healthy controls (CON). METHODS: Eleven T1D, 15 CON, 27 soldiers (Sol), 9 experienced climbers (Clim) and 6 international level of endurance athletes (Athl), all men, participated the study. We measured body composition, hemoglobin concentration ([Hb]), hematocrit (Hct), VO_{2max}, and determined tHb-mass, erythrocyte volume (EV), plasma volume (PV) and blood volume (BV) by optimized carbon monoxide rebreathing method. Physical activity (PA) was obtained from a questionnaire indicating the time spent on exercise per week. Statistical significance was defined as a p value of <.05. RESULTS: The main results are presented in a table below

Determinant	CON	T1D	Sol	Clim	Athl
N	15	11	27	9	6
Age (yr)	32±7	33±7	28±6	37±6	24±3
Height (cm)	182±4	177±9	180±7	179±7	185±4
Weight (kg)	85±11	76±11	81±9	81±10	73±7
LBM (kg)	70±7	64±8	69±8	66±8	65±6
BMI	26±3	24±3	25±2	25±3	21±1**
PA (min/wk)	296±159	270±160	337±150	670±468**	734±209**
VO _{2max} (ml/kg/min)	41±9	36±5	50±5***	55±7***	70±2***
[Hb] (g/dl)	14.3±0.6	14.4±0.7	13.9±0.6	14.3±0.4	15.0±0.8
Hct (%)	43±2	43±3	43±2	44±1	44±2
tHb-mass/BM (g/kg)	10.3±1.2	10.2±1.5	11.6±1.1*	12.1±1.4**	13.6±1.2***
BV/BM (ml/kg)	79±10	77±10	91±9*	93±11*	100±10***

though not significant, to lower total haemoglobin mass, blood volume and plasma volume expressed as per lean body mass compared to healthy controls, which suggest that this measurement may serve as a better early sign of anaemia compared to [Hb]. Greater tHb-mass was positively associated with higher VO_{2max}. However, with the same level of tHb-mass, blood volume and plasma volume, T1D posses lower aerobic capacity than healthy controls. In T1D, a given increase in tHb-mass equalled a smaller increment in VO_{2max} compared to CON, suggesting central (cardiac output) limitation to deliver O₂ and/or peripheral limitation (muscle) to consume O₂.

INTRODUCTION

According to Fick's equation $VO_2 = SV \times HR \times C(a-v) O_2$, blood oxygen carrying capacity and peripheral oxygen consumption play essential roles in determining aerobic capacity, besides blood volume (BV) affecting cardiac output. In diabetes with chronic kidney disease (CKD) anaemia is a common, and in early stages non-symptomatic, complication. However, kidney dysfunction develops gradually many years before CKD, causing changes in renal filtration, and possible leads to hypervolemia and/or anaemia.

PURPOSE

1) To study if T1D patients had anaemia or early signs of it in terms of low total haemoglobin mass (tHb-mass) or alternatively hypervolemia. 2) To study if the ratio of tHb-mass versus maximal oxygen uptake (VO_{2max}) is similar in T1D patients and healthy controls.

METHODS

Male subjects were 11 type 1 diabetes patients (T1D), 15 healthy controls (CON), 27 soldiers (Sol), 9 experienced climbers (Clim) and 6 international level of endurance athletes (Athl). T1D had normal kidney function and no diagnosed complications. Body composition was measured by bioimpedance method (InBody 720, South-Korea). Physical activity (PA) was obtained from a questionnaire indicating the time spent on exercise per week. Statistical significance was defined as a p value of <.05.

Table 1. Characteristics of subjects, physical activity (PA) and VO_{2max} (mean±SD, **p<.01, ***p<.001, compared to CON, One Way ANOVA)

Determinant	CON	T1D	Sol	Clim	Athl
N	15	11	27	9	6
Age (yr)	32±7	33±7	28±6	37±6	24±3
Height (cm)	182±4	177±9	180±7	179±7	185±4
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LBM (kg)	70±7	64±8	69±8	66±8	65±6
BMI	26±3	24±3	25±2	25±3	21±1**
Hct (%)	43±2	43±3	43±2	44±1	44±2
PA (min/wk)	296±159	270±160	337±150	670±468**	734±209**
VO _{2max} (ml/kg/min)	41±9	36±5	50±5***	55±7***	70±2***

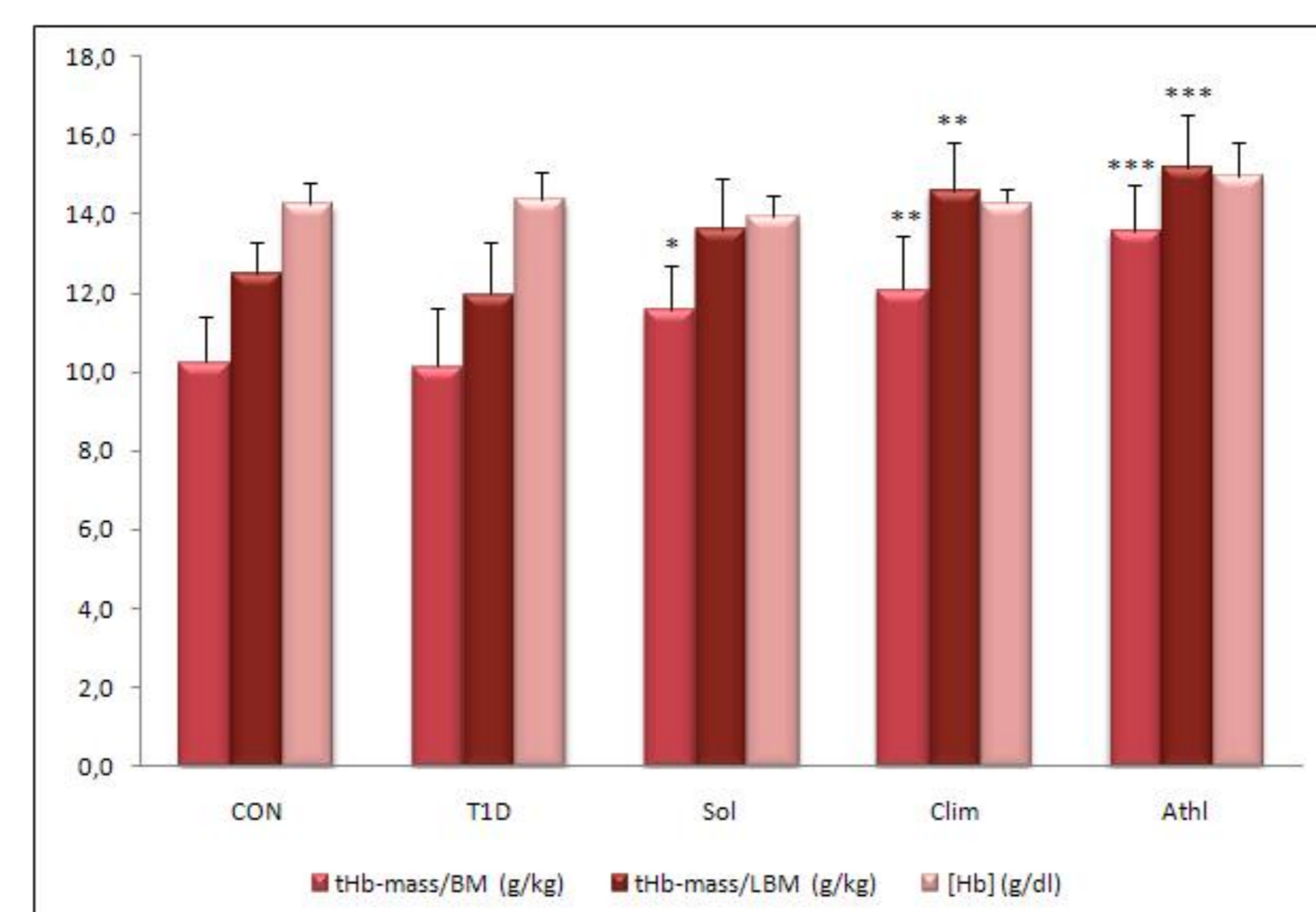


Figure 1. Total haemoglobin mass per body mass and lean body mass, and haemoglobin concentration (mean±SD, *p<.05, **p<.01, ***p<.001, compared to CON, One Way ANOVA)

We measured hemoglobin concentration ([Hb]) and hematocrit (Hct), and determined tHb-mass, erythrocyte volume (EV), plasma volume (PV) and BV by optimized carbon monoxide rebreathing method (SpiCO, BloodTech, Bayreuth, German). The values were divided by body mass (BM) and lean body mass (LBM). VO_{2max} was determined during maximal incremental exercise test, by a cycle ergometer (T1D, CON) or by running or walking (Sol, Clim, Athl).

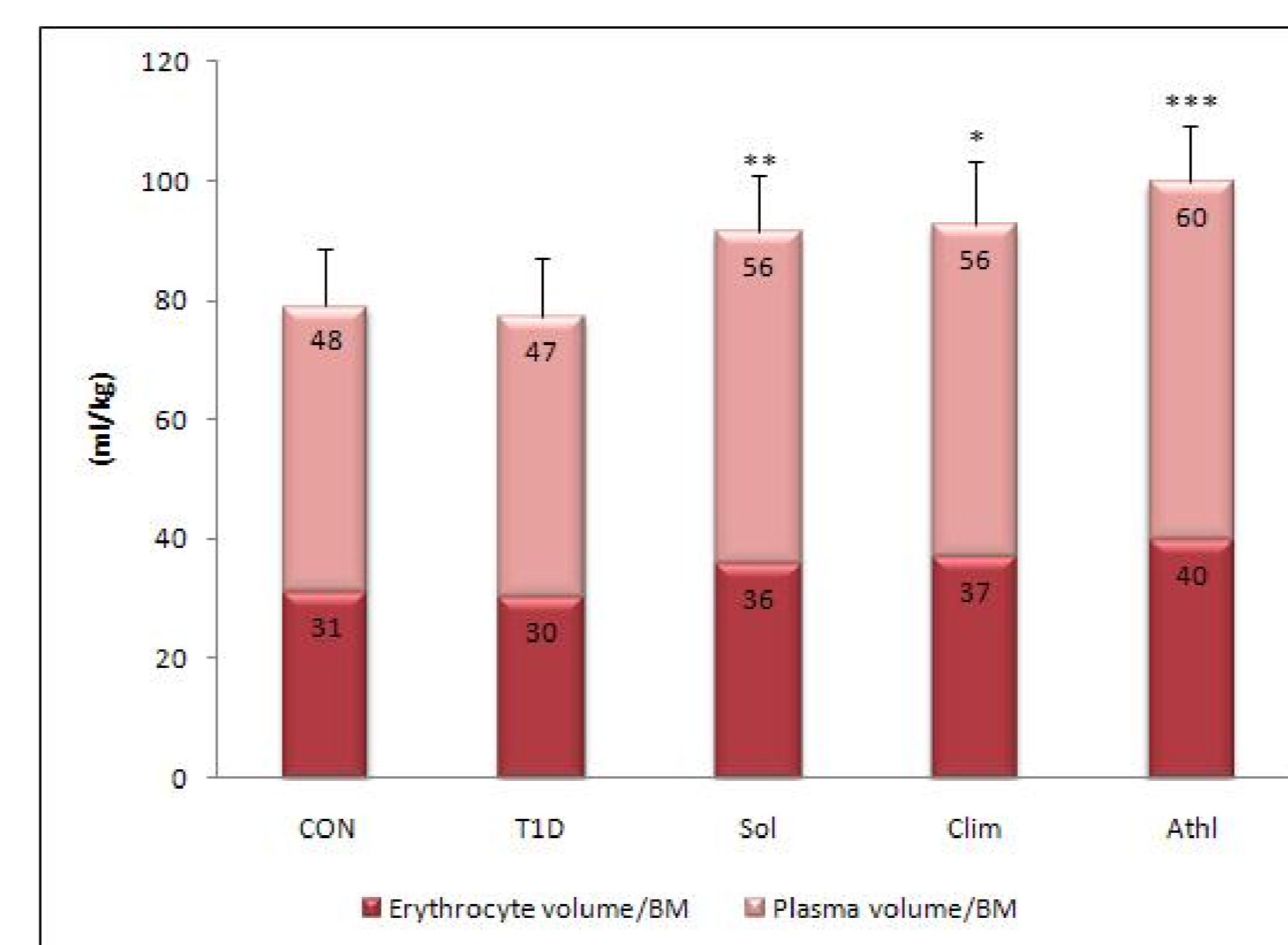


Figure 2. Blood volume per body mass (mean±SD), divided into (mean values in columns) erythrocyte volume and plasma volume (*p<.05, **p<.01, ***p<.001, compared to CON, One Way ANOVA)

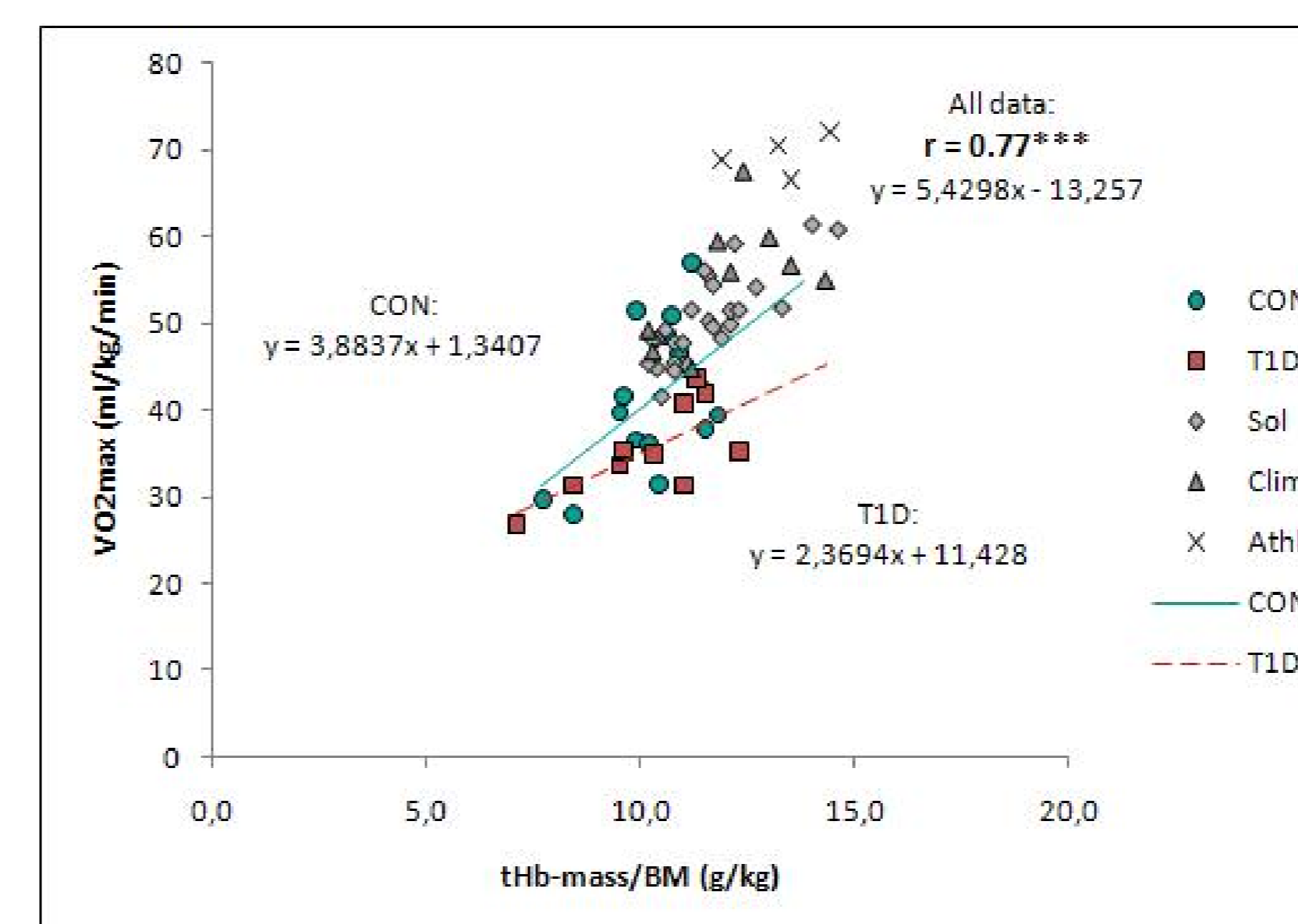


Figure 3. Total haemoglobin mass per body mass versus maximal oxygen uptake (***p<.001, n=66, Pearson Correlation)

RESULTS

Both T1D and CON had lower VO_{2max} (Table 1.), tHb-mass, EV, PV and BV compared to other groups (Fig. 1., 2.). For all subjects, the correlation coefficient between VO_{2max} and tHb-mass was .77 (p<.001), and after controlling with age and PA .71 (p<.001). The slope of the linear regression line was lower in T1D compared to CON and to all subjects (Fig. 3).

SUMMARY AND CONCLUSIONS

- T1D had a tendency, though not significant, to lower total haemoglobin mass, blood volume and plasma volume expressed as per lean body mass compared to healthy controls, which suggest that this measurement may serve as a better early sign of anaemia compared to haemoglobin concentration.

- Both in CON and T1D greater tHb-mass was positively associated with higher VO_{2max}. However, with the same level of tHb-mass, blood volume and plasma volume, T1D posses lower aerobic capacity than healthy controls.

- In addition, a given increase in tHb-mass equalled a smaller increment in VO_{2max} in T1D compared to CON, suggesting central (cardiac output) limitation to deliver O₂ and/or peripheral limitation (muscle) to consume O₂.

ACKNOWLEDGEMENTS

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