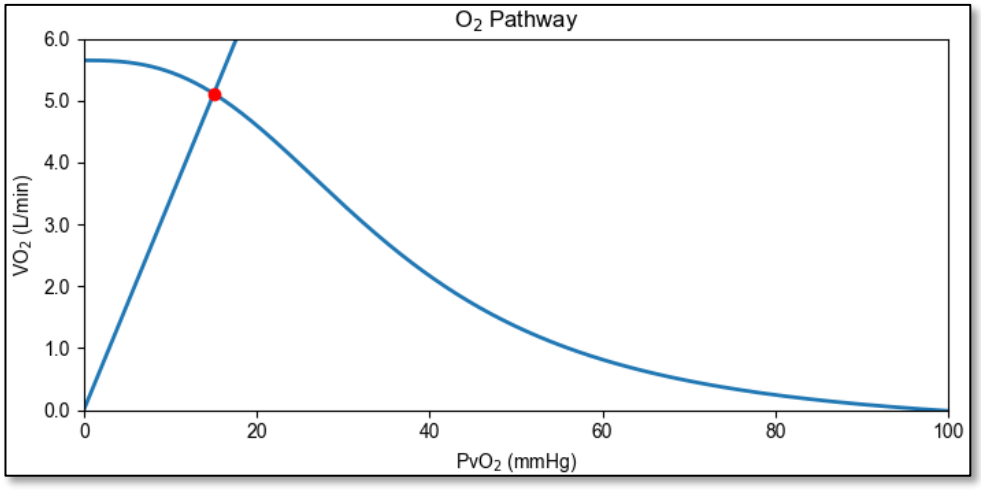

Helsinki O_2 Pathway Tool (HO_2PT)

User instructions

v1.4

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These User instructions are intended for use in conjunction with the Special Communications/Methodological Advances:

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Contents

1 Foreword 1

2 Intended use 1

3 Mathematical Modeling and Design 2

4 Getting started 5

5 Visual Layout 6

5.1 Side panel 8

5.1.1 Creating an event 8

5.1.2 Constructing a test 9

5.1.3 Editing an event 9

5.1.4 Deleting an event 9

5.1.5 Importing events 9

5.1.6 Comparing events 10

5.1.7 Plotting statistics 10

5.2 Details panel 12

5.2.1 Project details 13

5.2.2 Test details 13

5.2.3 Environmental details 15

5.2.4 The “Plot” button 16

5.2.5 The “Clear” button 16

5.3 Plot panel 17

5.3.1 The Figure 18

5.3.2 Figure tools 19

5.3.3 Load details 20

6 Default settings 21

6.1 Test options 21

6.2 Environmental options 22

7 Importing data 23

7.1 List of import steps 25

7.2 Sheet selection menu 26
7.3 Mass selection 27
7.4 Data table 27
7.4.1 Current selection indicator 30
7.4.2 Navigation buttons 30
7.5 Import using template files 30
8 Exporting data 31
8.1 Exporting active project’s content into a new datasheet file 32
8.2 Exporting active project’s content into imported file 34
8.3 Exporting only created content into a new datasheet file 36
8.4 Exporting only created content into imported file 37
9 How to 38
9.1 Plot figure without imported data 38
9.2 Plot figure with data entered by hand 39
9.3 Plot a test from imported data 41
9.4 Plot comparison figure 45
9.5 Plot statistics figure 47
9.6 Export data to new file 48
9.7 Export data to imported file 51
10 Troubleshooting 54
10.1 Invalid values 54

1 Foreword

Thank you for finding the Helsinki O_2 Pathway Tool (HO_2PT)! This tool has been designed and programmed as a bachelor's thesis project of an engineering student in health technology. The idea for the tool came from the professionals of Helsinki Sports and Exercise Medicine Clinic (HULA) and Department of Sports and Exercise Medicine, Clinicum, University of Helsinki. The tool is based on the integrated O_2 pathway model by Peter D. Wagner (e.g., Wagner PD. *Sports Med*. 1991;11(3):133-42; Wagner PD. *Med Sci Sports Exerc*. 1992;24(1):54-8; Wagner PD. *Annu Rev Physiol* 1996;58:21-50; Wagner PD*. J Breath Res* 2008;2:024001; Wagner PD. *Comput Methods Programs Biomed*. 2011;101(2):109-14; Wagner PD. *J Muscle Res Cell Motil*. 2022. DOI: 10.1007/s10974-022-09636-y) and enables the description of O_2 uptake ($\dot{V}O_2$) and its components both quantitatively and graphically. The modeling is based on the Fick equation and the Fick law of diffusion with some previously described assumptions (e.g., Dash et al. *Eur J Appl Physiol* 2016;116(1):97-113; Legendre et al*. Int J Cardiol* 2021;330:120-127). The tool can be used with existing or new data.

There is no technical support for the source code. However, the code is free to use and can be modified to fit one's individual needs. The code can be downloaded from GitHub.

2 Intended use

The HO_2PT is intended to be used to analyze $\dot{V}O_2$, its components, and their alterations of a single test subject or a group-level dataset. It is intended to be used as a tool for anyone researching $\dot{V}O_2$, for example, in the fields of scientific research, education, athlete's physical performance testing and coaching. It can also be used in research of pulmonary, cardiovascular, and skeletal muscle conditions and disorders, for example, for identifying and monitoring factors limiting aerobic capacity and physical performance. Thus, if the tool and the information it provides will be demonstrated by future peer-reviewed original studies to be suitable for appropriate patient groups in clinical patient work as a part of diagnostics, monitoring, and decision-making, one of its intended use environments may be clinical patient work in the future. The tool can also be used to study effects of environmental factors and medications on physiological responses.

3 Mathematical Modeling and Design

The HO_2PT is based on the integrated O_2 pathway model originally presented by Peter D. Wagner (e.g., Wagner PD. *Sports Med*. 1991;11(3):133-42; Wagner PD. *Comput Methods Programs Biomed*. 2011;101(2):109-14, more references above in Foreword). The modeling is based on the Fick equation and the Fick law of diffusion with a few previously described approximations (e.g., Legendre et al. *Int J Cardiol* 2021;330:120-127). Equations used to solve parameters needed for the modeling are demonstrated in Table 1.

Table 1 – List of parameters, their abbreviations, supported units, procurement method of and equations used in the O_2 Pathway Tool.

Variable	Abbreviation	Units	Measured/Calculated	Equations
Pulmonary O_2 uptake	$\dot{V}O_2$	L/min, mL/min	Measured, calculated	$\dot{Q}\ x\ C(a-v)O_2$
Heart rate	HR	bpm	Measured	
Stroke volume	SV	mL	Measured, calculated	$\frac{\dot{V}O_2}{HR\ x\ C(a-v)O_2}$
Cardiac output	$\dot{Q}$	L/min	Measured	$SV\ x\ HR$ $\frac{\dot{V}O_2}{C(a-v)O_2}$
Hemoglobin concentration	[Hb]	g/L, g/dL	Measured	
Arterial O_2 saturation	SaO_2	%	Measured	
Arterial O_2 content	CaO_2	mL O_2 / L blood mL O_2 / dL blood	Calculated	$1.34\ x\ [Hb]\ x\ SaO_2$ $C(a-v)O_2 + CvO_2$
Venous O_2 saturation	SvO_2	%	Measured, calculated	$\frac{CaO_2 - C(a-v)O_2}{1.34\ x\ [Hb]}$
Venous O_2 content	CvO_2	mL O_2 / L blood mL O_2 / dL blood	Calculated	$1.34\ x\ [Hb]\ x\ SvO_2$ $CaO_2 - C(a-v)O_2$
Arterial-venous O_2 difference	$C(a\text{-}v)O_2$	mL O_2 / L blood mL O_2 / dL blood	Calculated	$CaO_2 - CvO_2$ $\frac{\dot{V}O_2}{\dot{Q}}$
Convective O_2 delivery	$\dot{Q}aO_2$	mL/min	Calculated	$\dot{Q}\ x\ CaO_2$
Blood temperature	T	°C, K, F	Measured, calculated	
pH	pH		Measured, calculated	
Partial venous O_2 pressure	PvO_2	mmHg	Measured, calculated	
Diffusive O_2 conductance	DO_2	mL/min/mmHg	Calculated	$\frac{\dot{V}O_2}{2\ x\ PvO_2}$

Oxygen transport from the air to the mitochondria follows a well-established sequence:

1. Ventilation that carries inspired air to the pulmonary alveoli.
2. Diffusion of oxygen from alveolar gas into the pulmonary capillary blood.
3. Convective O_2 transport from the capillaries to the pulmonary veins, left heart and from there to the microvasculature of various body tissues.
4. Unloading of O_2 from Hb in red cells in microvasculature and subsequent passive diffusion to the mitochondria where O_2 is used to produce ATP via oxidative phosphorylation.

The Fick equation (Equation 1) expresses parametric limits and physiological characteristics of cardiorespiratory fitness and is historically one of the first attempt to define the oxygen transport cascade.

$$\dot{V}O_2 = \dot{Q} \times C(a\text{-}v)O_2, \text{ where} \qquad \text{(Equation 1)}$$

$\dot{V}O_2$ = oxygen uptake

$\dot{Q}$ = cardiac output

$C(a\text{-}v)O_2$ = arterial-venous oxygen difference

Unfortunately, the Fick equation fails to distinguish detailed limitations/improvements/declines in the O_2 cascade sequence from inspired air to the mitochondria. While the effect of $\dot{Q}$ on $\dot{V}O_2$ is simplistic in nature, challenges arise when interpreting $C(a\text{-}v)O_2$. This is because $C(a\text{-}v)O_2$ is affected by numerous factors such as pulmonary ventilation, matching of ventilation to $\dot{Q}$, diffusion of O_2 from the alveoli into the pulmonary circulation, affinity of Hb for O_2, total Hb mass and blood volume (determining [Hb]), $\dot{Q}$, systemic and local control of blood flow, number and size of capillaries, mitochondrial density, and oxidative enzyme activity. To overcome the obstacles of using the Fick equation alone, Peter Wagner and his colleagues presented a graphical model roughly 30 years ago (late 1980's - early 1990's) to characterize how all transport steps contribute to $\dot{V}O_{2max}$. The key concept was to introduce Fick's law of diffusion (Equation 2) to express peripheral O_2 diffusion from capillaries to mitochondria into the model:

$$\dot{V}O_2 = DO_2 \times (PcapO_2 - PmitoO_2), \text{ where} \qquad \text{(Equation 2)}$$

DO_2 = diffusive O_2 conductance

$PcapO_2$= partial pressure of O_2 in capillaries

$PmitoO_2$ = partial pressure of O_2 in mitochondria

Equation 2 can be simplified by two assumptions. First, as $PmitoO_2$ is around 1-3 mmHg during (near) maximal exercise, and partial microvascular O_2 pressure resides between those of arteries (~90–100 mmHg) and veins (~20–40 mmHg), making the mean $PcapO_2$ to be commonly about 40-50 mmHg, $PmitoO_2$ may be assumed to be zero. Second, $PcapO_2$ may be replaced with a constant, *k*, multiplied by partial venous O_2 pressure (PvO_2). This is because PvO_2 is proportional to $PcapO_2$, when DO_2 is assumed to be uniform along the capillaries with homogeneous blood flow distribution. Consequently, Fick's law of diffusion can be simplified as follows (Equation 3):

$$\dot{V}O_2 = DO_2 \times k \times PvO_2 \qquad \text{(Equation 3)}$$

While the described system and the Equations 1-2 apply equally from rest to maximal exercise, it is only from near-maximal to maximal exercise that the graphical display is applicable with little need for approximations. This particularly means that $PmitoO_2$ must be low enough to be ignored in the calculations, when it does not affect the graphical display based on Wagner's and his colleagues' model.

4 Getting started

When you are reading this document, there is a high possibility you have already downloaded the tool from HULA's website. If this is not the case, here are the necessary steps to get started:

HO_2PT is developed for Windows and compiled separately for Linux and MacOS operating systems. If possible, it is preferable to run HO_2PT on Windows or Linux operating systems.

1. Go to HULA's website.
2. Click on the download link that corresponds to your operating system.
3. Unpack the downloaded file.

Windows / Linux:

4. Inside the HO2PT folder of the unpacked file, double left click on the "**HO2PT.exe**" file to run the tool.

MacOS:

5. Move the unpacked HO2PT app to your Applications folder.
6. Double left click HO2PT to run the tool.
7. When using the tool for the first time, macOS will once inform you that the application is downloaded from the internet.
8. Click Open to run the tool.

You can create a desktop shortcut from the "**HO2PT.exe**" file. With Windows systems this is done by right clicking the file and selecting "**Create a desktop shortcut**".

5 Visual Layout

The HO_2PT ‘s layout is constructed with three main components (Figure 1):

1. Side panel
2. Details panel
3. Plot panel

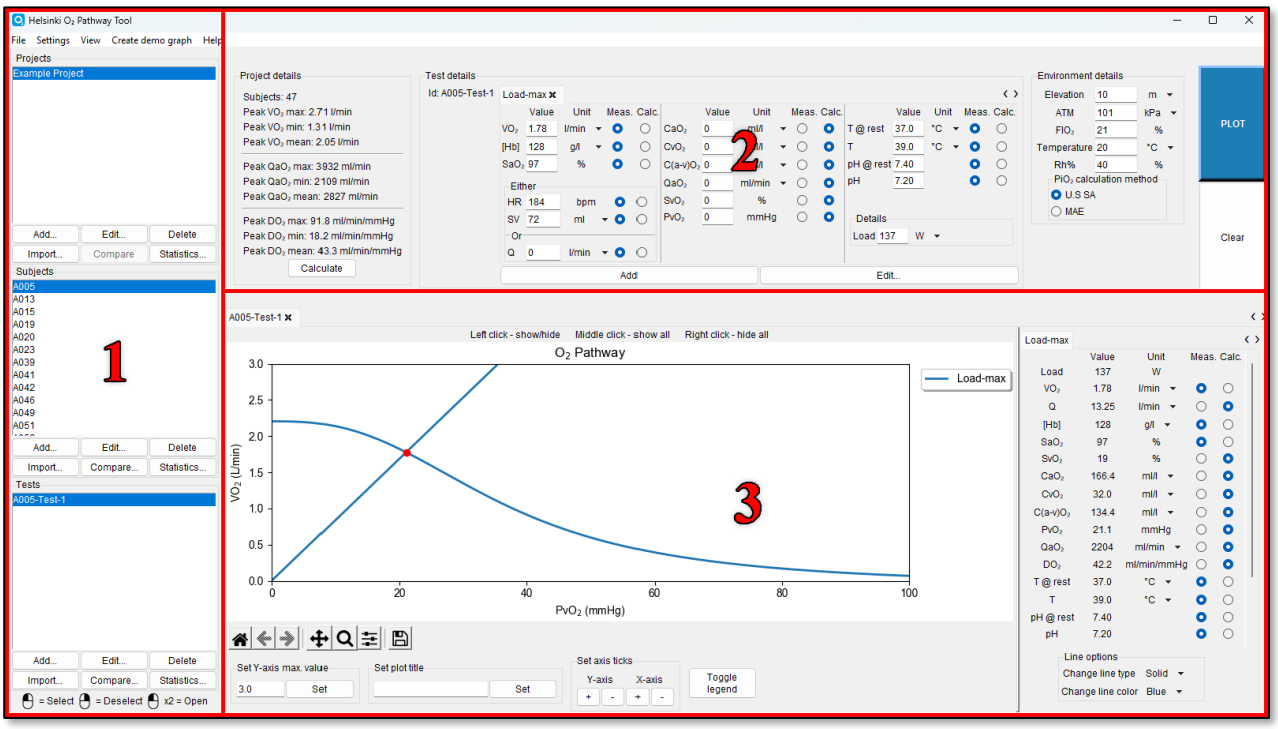


Figure 1 – The main components of the layout, side panel (1), details panel (2), plot panel (3).

You can control the visibility of these panels from the main menu bar's "**View**" menu (top part of the tool). You can also adjust the size of the panels by holding your cursor above the edge of the panel and dragging it to fit your needs (Figure 2). When holding the cursor above the edge of the panel, the shape of the cursor changes to inform you about this functionality.

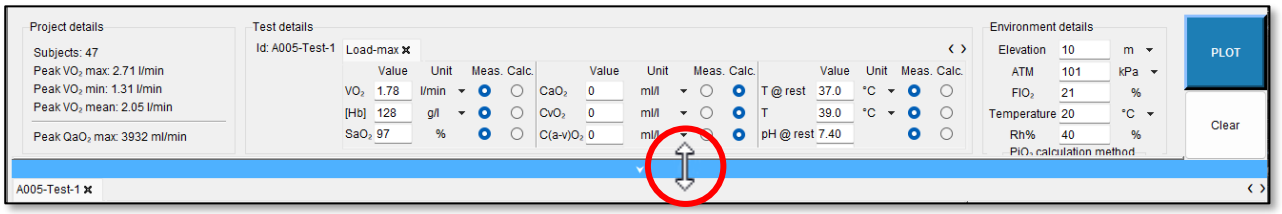


Figure 2 – The cursor changes when holding the cursor on the border of a panel. The size of the panel can be adjusted by dragging.

If the panel's content does not fit the resized panel, a blue bar with white arrow is shown. When you double left click on the bar, the panel is returned to its default size.

The current state of the layout is stored when closing the tool, so you can continue automatically with the same set-up you ended working with.

5.1 Side panel

The side panel is constructed with three modules (Figure 3):

1. Projects module
2. Subjects module
3. Tests module

These modules help you control their respective content. Every module contains a list of created events which you can add, edit, or delete, if needed. The buttons in every module have the same functionalities. You can select a list item by left clicking and deselect by right clicking the item.

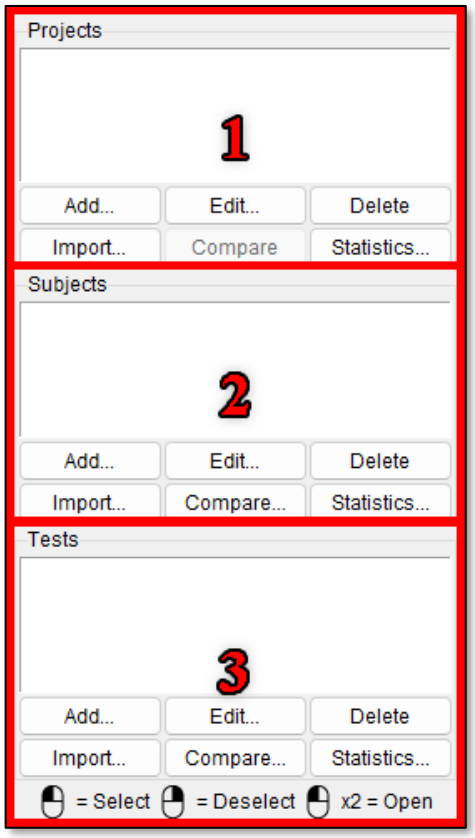


Figure 3 – The components of the side panel: project module (1), subject module (2), test module (3).

5.1.1 Creating an event

Once the "**Add…**" button is pressed a pop-up window is shown (Figure 4) to give you a choice of adding an event to the list or adding event's selected content to the details panel (more info about this can be found here). When selecting the first option, a new event is created and appended to the corresponding list.

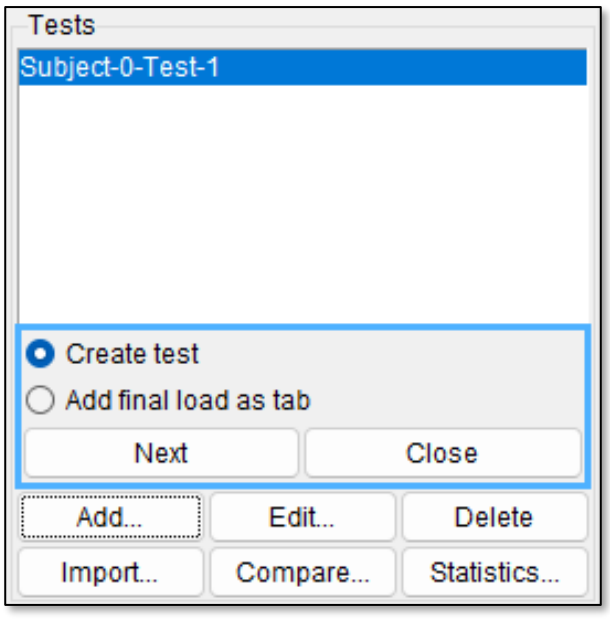


Figure 4 – After "Add…" button is pressed a pop-up window appears. To construct a test by yourself, you can use the secondary options "Add…as tab" in each module.

5.1.2 Constructing a test

In addition to working with imported or created events, you can also construct a plottable event yourself by combining data from different events. This is achieved by using the secondary options in each module's pop-up window (Figure 4). After selecting the content to be added and clicking the "**Next**" button, the content is added to the details panel (more info about this here) where you can still modify the data. You can repeat this as many times as necessary. You can also combine content of multiple events to a single tab in the details panel, which can be useful when grouping content (e.g. men & women). These functionalities enable you to add data from different projects, subjects, or tests to be plotted in the same figure.

5.1.3 Editing an event

Names of the events are formed based on the imported data or indexed default names. You can edit the name at any time by selecting the event to be edited and clicking the "**Edit…**" button (Figure 4). A pop-up window is shown where you can rename the event.

5.1.4 Deleting an event

If you want to delete an event, simply select the event to be deleted and click the "**Delete**" button (Figure 4).

5.1.5 Importing events

The "**Import…**" button starts the data import wizard (Figure 4). More about the data import wizard can be found here.

5.1.6 Comparing events

To compare events, you must first choose at least two events from the list (Figure 5). Event selection can be performed by:

1. Holding **CTRL key + LEFT** clicking individual events.
2. Holding **SHIFT key + LEFT** clicking an event to select every event between the first and the last selection.

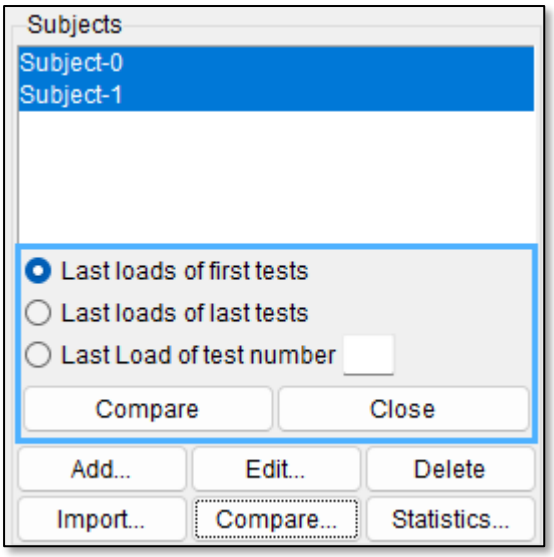


Figure 5 – Comparison options for subjects. The comparison is done by maximum loads.

After selection, click the "**Compare…**" button (Figure 5) to open the comparison options pop-up window. From the options pop-up you can choose what content to compare. After clicking the "**Compare**" button in the pop-up window (Figure 5), the wanted content is moved to the details panel where you can still modify them and create a figure. Only the maximum loads of the selected events are considered for comparison.

5.1.7 Plotting statistics

You can create a statistics figure of a single or multiple events' content. First, you must select the wanted events and click "**Statistics…**" button and an options pop-up window is shown (Figure 6). There are three possible statistical methods that can be used:

1. Mean (SD) - Standard deviation
2. Median (IQR) - Interquartile range
3. Mean (95 % CI) - Confidence interval of 95 %

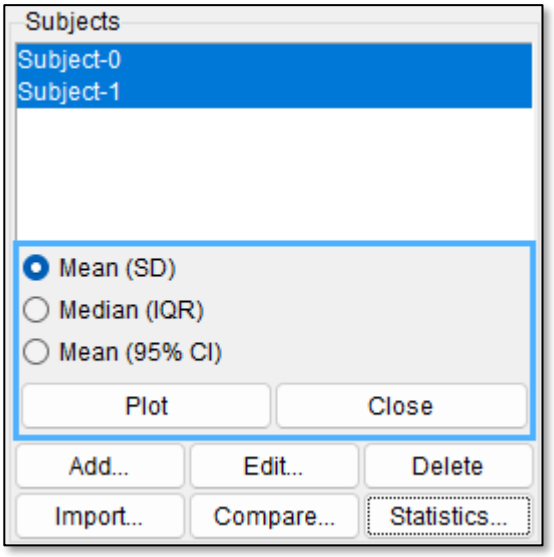


Figure 6 – Statistical options for subjects. The options are the same for all the instances.

Every statistic figure is constructed from three tabs and numerical values for each tab are calculated (Figure 7). After creating the statistic figure, the calculated values are shown in the plot panel's load details module (more about the details module can be found here).

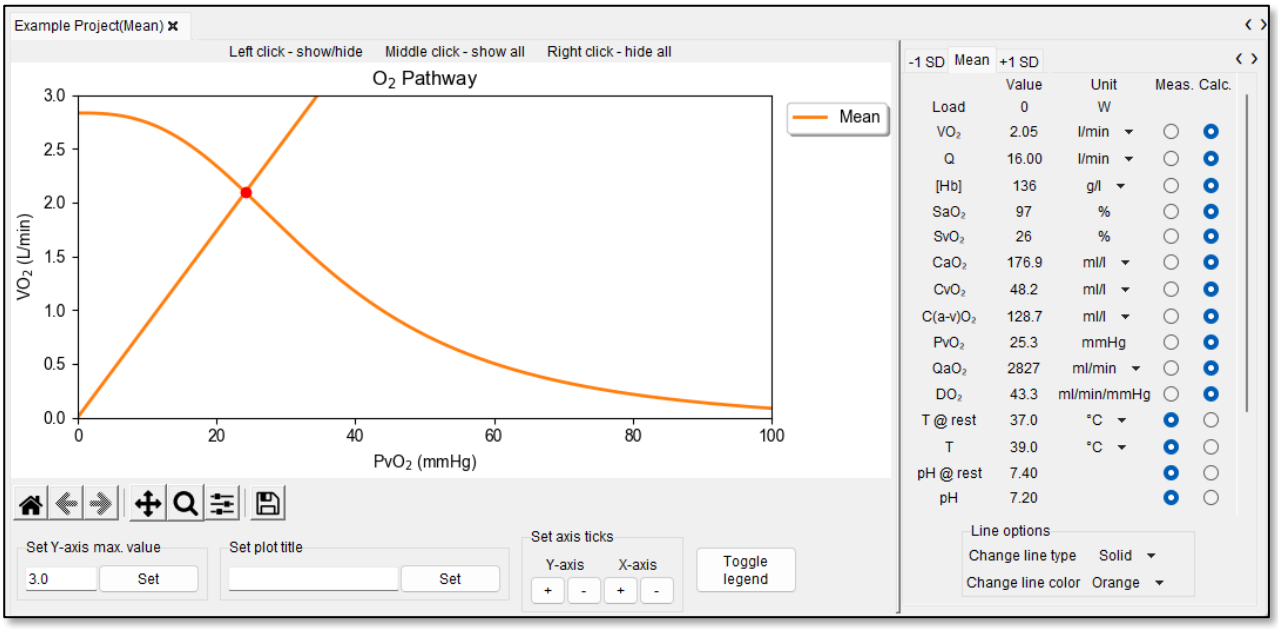


Figure 7 - Example of plotting statistics. The figure has three loads: "-1 SD", "Mean" and "+1 SD", which contain the corresponding quantitative results.

5.2 Details panel

The details panel (Figure 8) enables you to gather and view the wanted information to be plotted. The panel's content is updated when you select a test or add content from the side panel's modules. The details panel is constructed with four modules:

1. Project details
2. Test details
3. Environmental details
4. The "**Plot**" button

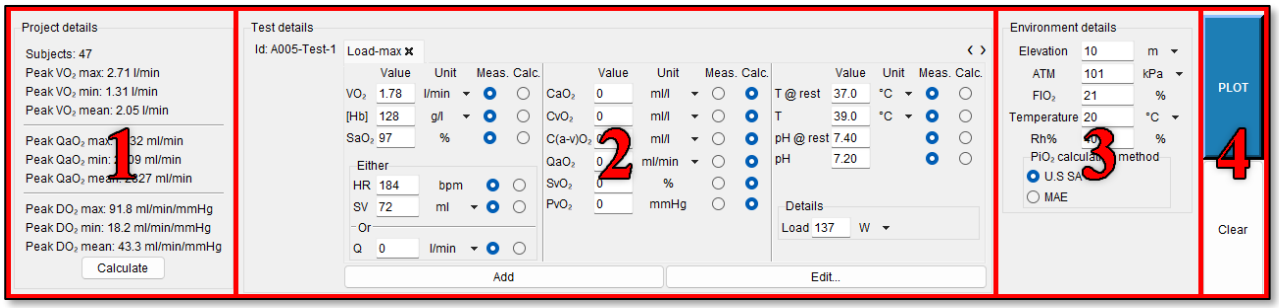


Figure 8 – The components of the details panel. Project details (1), test details (2), environmental details (3) and the "Plot" button (4).

You can control the visibility of the whole details panel and each of its modules from the "**View**" menu of the main menu bar (top part of the tool).

5.2.1 Project details

Project details module (Figure 9) holds statistical information of the currently selected project. The subject count is updated automatically when a new subject is added to the project. The peak, min, and max values are updated, when the "**Calculate**" button is clicked or when a project statistics figure is plotted. Calculation of project statistics is based on the values of maximum loads of the subjects' tests in the selected project.

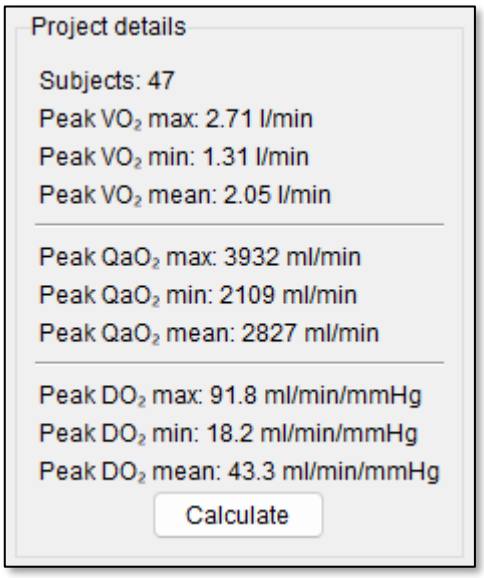


Figure 9 – Project details shows and computes statistical information about VO_2, QaO_2, and DO_2 values in the currently active project

5.2.2 Test details

Test details (Figure 10) contains two modules:

1. Details
2. Load notebook

Every tests' loads are handled in the tool as tabs. Every tab contains the details of the corresponding load. Here you can edit the values and used units and mark the parameter as measured or calculated for every load.

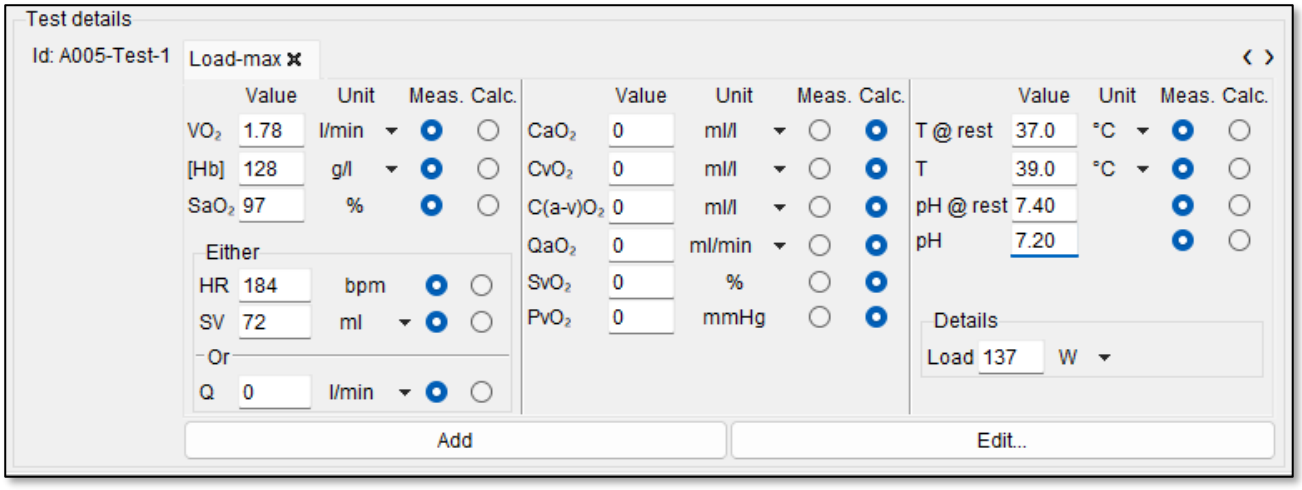


Figure 10 – Values of a load are stored in tabs, and they can be adjusted by input, dropdown menus or radiobuttons.

The change of a unit in one load is implemented automatically on every load of the active test. These values are used to model the O_2 pathway and create a figure. Even if the data are imported, you can safely edit the parameters. The tool will not override imported data, so the changes made to the parameters are stored only in the details module and once you select another test the changes are lost. If you are entering values by hand, please make sure you use dot rather than a comma to separate integers from decimals.

If you are constructing a test by hand, you can add a load by clicking the "**Add**" button (Figure 10). After clicking the button, a new tab is appended to the notebook with a default indexed name. You can edit the name of the load any time by clicking the "**Edit…**" button (Figure 10). To delete a load, click the small cross in the tab. Deletion of a tab is confirmed with a pop-up window.

If you have imported data and realize that the default units are different from the ones used in the data, you can update the units in the whole project by changing the default settings in the "**Settings**" menu in the main menu bar (in the top part of the tool). The change in the settings is automatically implemented in the whole tool. More about the default settings can be found in the next chapter.

5.2.3 Environmental details

Environmental details (Figure 11) let you modify the circumstances under which the test was performed. These values are implemented for every load. However, even if you set the environmental details in the default settings or in the environmental details, they are not currently considered in the modeling process. Therefore, modeling O_2 pathway with environmental details is not supported in the current version of HO_2PT.

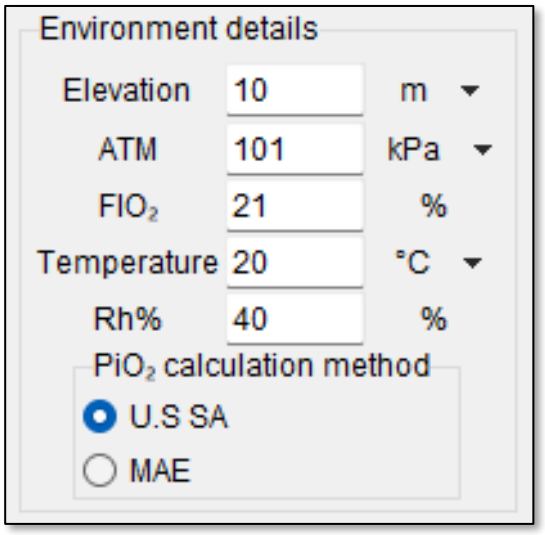


Figure 11 – Environmental details of the conditions the measurements were done can be included to the results but does not influence the modeling of O_2 pathway.

Modeling with the environmental details is not supported in this version of the HO_2PT.

5.2.4 The “Plot” button

To create a figure with the entered or imported values in the test details and environmental details, click the “**Plot**” button (Figure 8). After clicking the button, the HO_2PT validates the given values and performs the calculations. If the values are invalid or the used units are incorrect, an error message is shown below the main menu bar (Figure 12). The error message contains information about the load that the tool was unable to calculate. If the values are valid, a figure is shown in the plot panel (more about this can be found here).

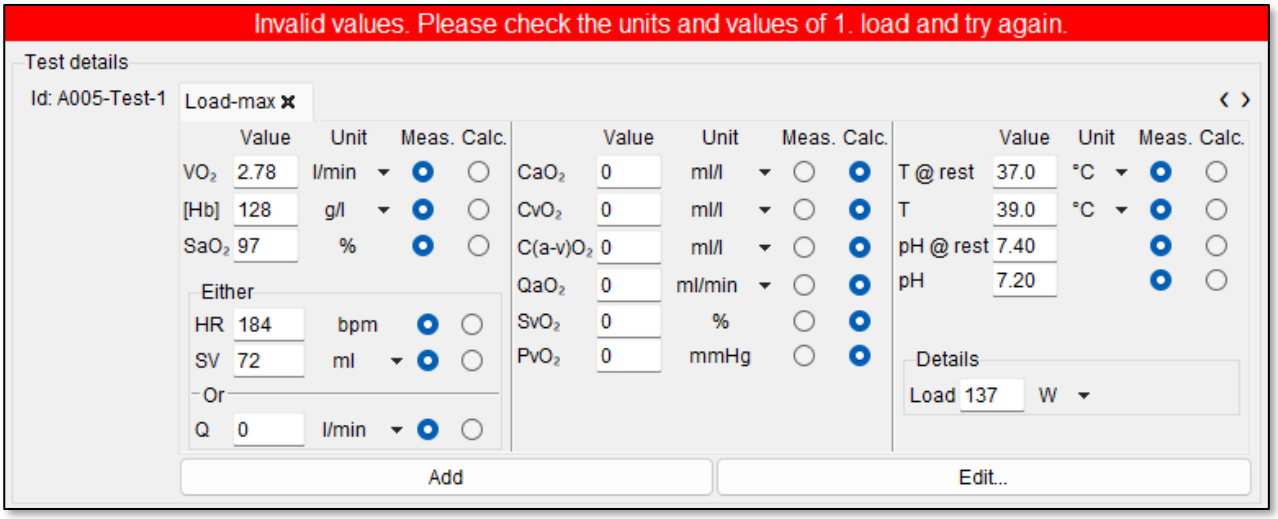


Figure 12 – An error message is shown with red background under the main menu bar of the window.

5.2.5 The “Clear” button

To clear the test details panel, click the “**Clear**” button. This will deselect and remove any data of the currently active test.

5.3 Plot panel

The plot panel (Figure 13) is a key function of the HO_2PT. The plot panel illustrates the graphical output and the quantitative values of the modelling process. The plot panel is constructed with tabs that hold the results of the modeling process. This enables you to handle multiple models at the same time. There is no limit for the number of tabs that can be created, and you make the tab active by left clicking the tab. If your tabs exceed the width of the window, you can scroll them through by using the mouse wheel or by clicking the "**<**" or "**>**" buttons. You can remove a tab by clicking the small cross inside the tab. Removal of a tab is confirmed by a pop-up window, so you cannot accidentally remove a tab and lose its information.

The plot panel's tabs are constructed with three main modules:

1. The figure
2. Figure options
3. Load details

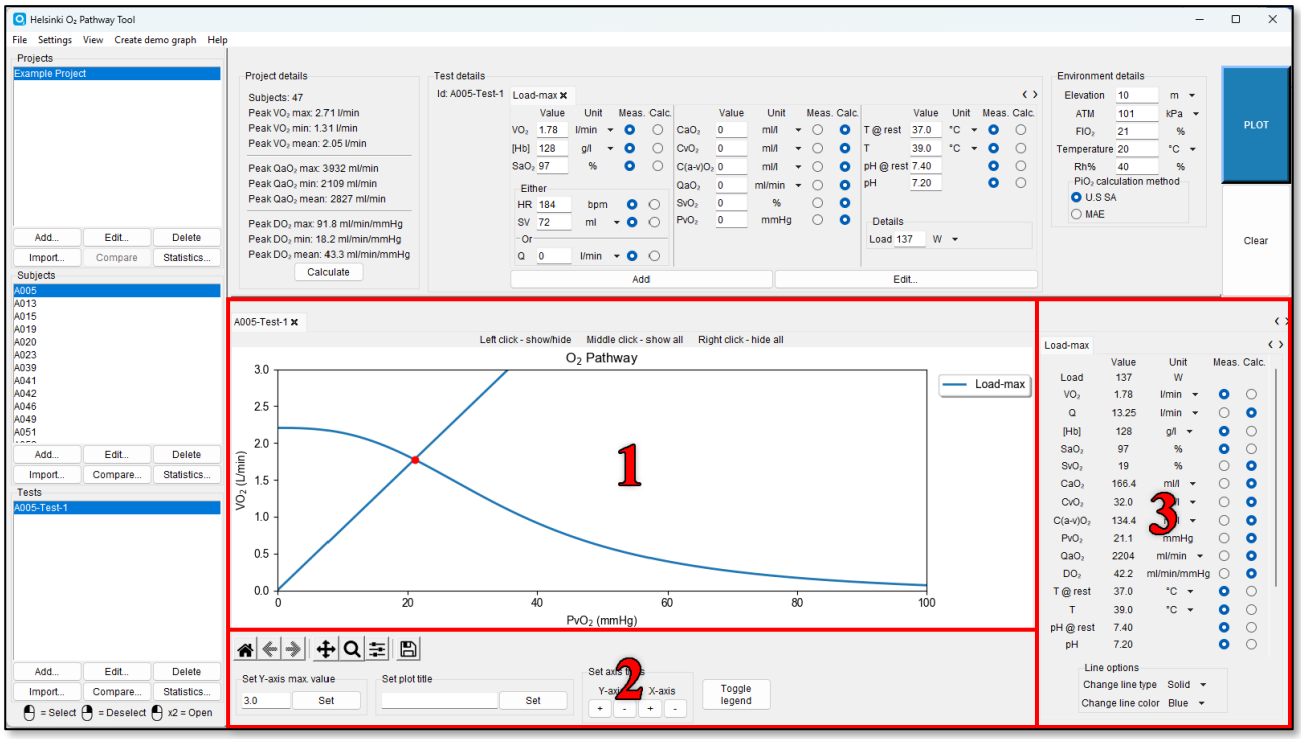


Figure 13 – The main components of a plot panel's tab: the Figure (1), Figure options (2), load details (3).

5.3.1 The Figure

The figure has two graphs: the diffusion line and the convection curve (Figure 14). Drawing of the graphs is based on Peter D. Wagner's integrated O_2 pathway model (e.g., Wagner PD. *Sports Med*. 1991;11(3):133-42; Wagner PD. *Med Sci Sports Exerc*. 1992;24(1):54-8; Wagner PD. *Annu Rev Physiol* 1996;58:21-50; Wagner PD. *J Breath Res* 2008;2:024001; Wagner PD. *Comput Methods Programs Biomed*. 2011;101(2):109-14; Wagner PD. *J Muscle Res Cell Motil*. 2022. DOI: 10.1007/s10974-022-09636-y) that is based on the Fick principle and Fick's law of diffusion and equations listed here. The intersection of the graphs is detected and marked by a red dot. Every load is plotted as a separate unit, meaning that if you for example modify the color of a graph representing a specific load, the change is implemented on both the diffusion line and convection curve. There is no limit on the number of loads that can be used.

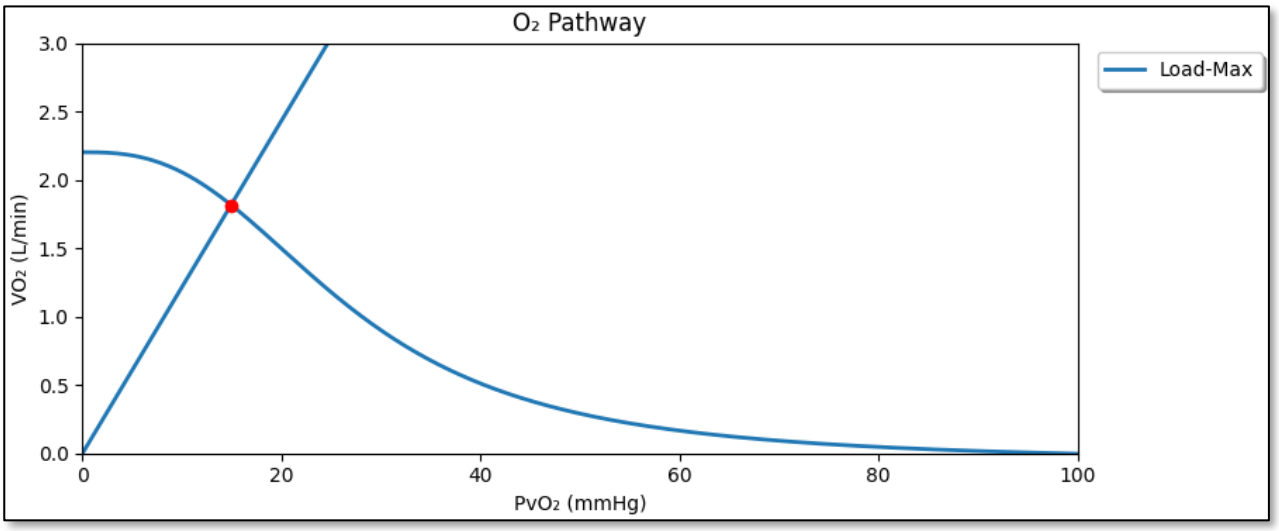


Figure 14 – Example graph of Wagner's model, that combines Fick's law and principle to demonstrate O_2 pathway as an integrated system limiting O_2 uptake.

You can toggle the visibility of a graph by left clicking the line itself or its corresponding line in the figure legend. Right clicking anywhere on the figure hides every graph. Middle clicking anywhere on the figure shows every graph.

The units of the y-axis and its label are determined automatically by the units used when creating the figure. You can change the unit of the y-axis by selecting the wanted unit for $\dot{V}O_2$ from the unit drop-down menu in the adjacent load details.

The maximum value of the y-axis is determined by the maximum value of the convective O_2 delivery. After the maximum value is calculated, the value is rounded up to the closest whole number. The number of ticks is set automatically, but you can increase of decrease the number of ticks in the figure options below the figure.

The title of the figure can also be changed from the figure options below the figure.

5.3.2 Figure tools

Figure tools enable you to modify the appearance of the figure. The basic tools are:

	Home button: Return to the default settings if you have moved or zoomed the figure.
	Arrow buttons: Cycle through changes. Every action on the figure creates a new view, which you can cycle with these buttons.
	Move: While holding left click on the figure, move the mouse to drag the figure to wanted location.
	Zoom: To zoom in certain location on the figure, draw a rectangle on the area you want to focus on by holding the left click on the figure and moving the mouse.
	Adjust the figure: If the proportions are not suitable or a title is not fully visible, you can adjust the aspect ratio and positioning of the whole figure.
	Save the figure: Use this, if you want to save only the figure as an image file. The image is saved as a .png file to the working directory of the tool in your operating system.

Other options included are (Figure 15):

1. Y-axis max value setter – Input the wanted maximum value of the y-axis and click "**Set**"
2. Plot title setter – Input the wanted title for the figure and click "**Set**"
3. Increment/Decrement of axis ticks – Add or remove ticks by clicking the "**+**" or "**-**" buttons
4. Toggle legend visibility – Click to toggle the visibility of the figure legend

Figure 15 – In addition to basic figure tools, there are four additional tools to modify the appearance of the figure.

5.3.3 Load details

The load details contain all the quantitative (calculated or measured) values of the currently selected load (Figure 16). You can cycle through the load tabs to see their respective details. If the number of tabs exceeds the width of the window, you can scroll through the tabs by using the mouse wheel or clicking the "**<**" or "**>**" buttons.

You cannot change the values of the parameters, but you can still modify the unit and mark the parameter as calculated or measured. When updating the unit from the drop-down menu next to the numerical value, the tool automatically converts the value of the parameter to the corresponding unit.

You can modify the load's line type and color in the figure by the options in the load details. There are four different line types and 10 different color options to choose from. The options are as follows:

Line types	
Solid	———
Dotted	- - - - -
Dashed	— — —
Dashdot	— - — -

Line colors	
Blue	Orange
Green	Red
Purple	Brown
Pink	Gray
Olive	Cyan

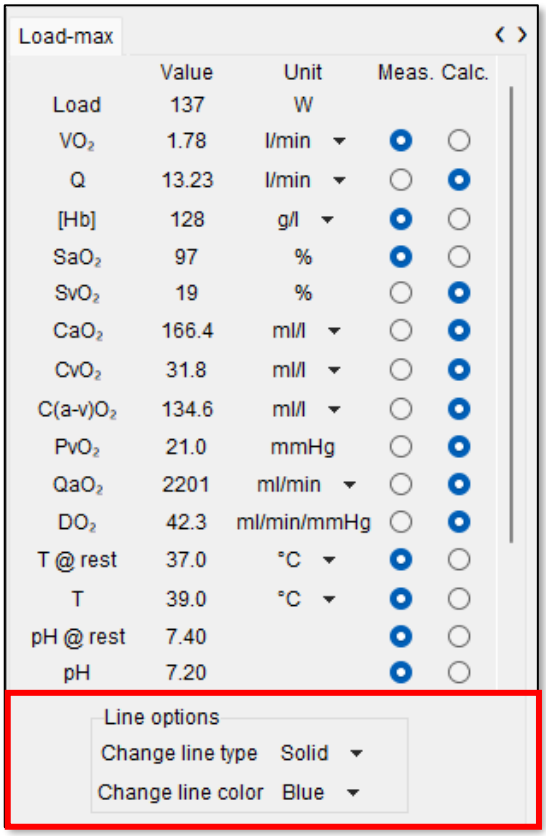


Figure 16 – Every load of the modeled test is saved as a tab. The details tab contains the quantitative results, used units and information about the value if it is measured or calculated. Details tabs also have the line options for the load's graph.

6 Default settings

To save your preferred settings for the default values and units used in the model, you can set and modify the default settings. This can be done in the "**Settings**" menu in the top menu bar (in the top part of the tool). List of supported units can be found here. The default settings window is constructed of two modules (Figure 17):

1. List of options
2. Details

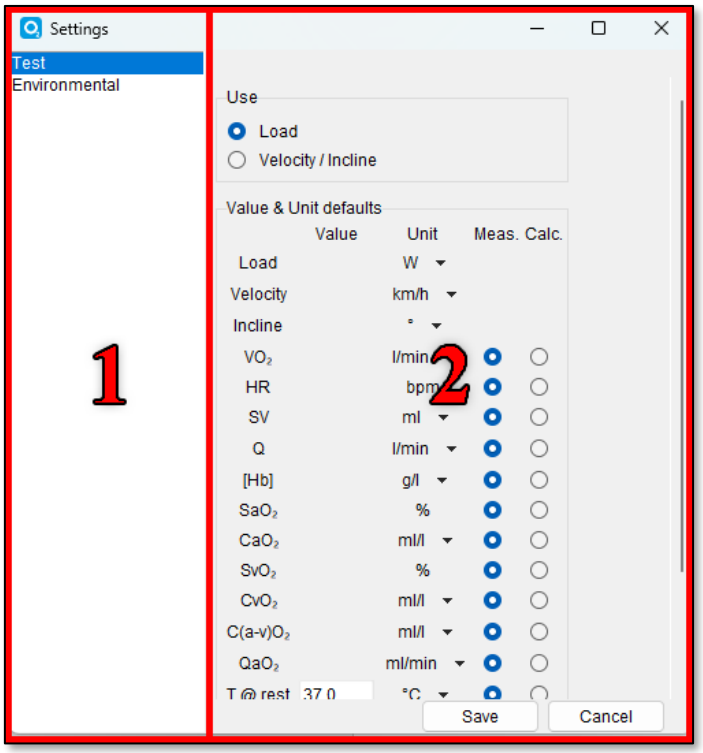


Figure 17 – The components of the default settings window: list of options (1) and details panel (2).

6.1 Test options

You can set the test mode that is used by default in every test. Currently the HO_2PT supports "**Loads**" referring to exercise stress tests performed on a cycle ergometer and "**Velocity/Incline**" referring exercise stress tests performed on a treadmill. Selection of the test mode will affect the details panel's content.

Default settings allow you to set default units for every parameter and default values for pH and blood temperature. The options for parameter units are listed in the drop-down menus, which can be opened by clicking the wanted unit. Once you click the "**Save**" button (Figure 17), the values and units are saved and implemented in the details panel. You can close the settings window by clicking the "**Cancel**" button.

6.2 Environmental options

The same functionalities apply to environmental options (Figure 18). You may change and save the values and/or units and they will be implemented in the details panel. However, modeling the O_2 pathway with environmental conditions is not yet supported.

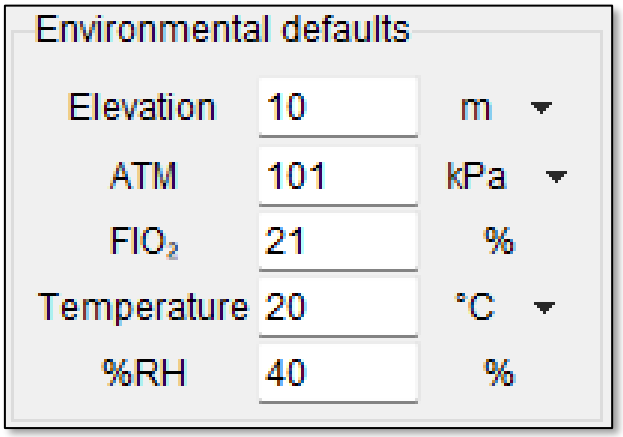


Figure 18 – Default values and units can be set, the same as in test options.

The environmental parameters are:

Parameter	Unit
Elevation	m, km, ft
Atmospheric pressure, ATM	kPa, bar, psi, mmHg
Fraction of inspired oxygen, FIO_2	%
Temperature	°C, F, K
Relative humidity, %RH	%

Modeling with the environmental details is not supported in this version of the HO_2PT.

7 Importing data

The HO_2PT features a data import wizard that is intended to enable generic data import from any structure of data. There is no standard for how a dataset should be formed so the data import wizard has to be able to import data even if the values are arranged horizontally or vertically. The data import wizard can be started by clicking the "**Import…**" button or selecting "**File**" -> "**Import…**" from the main menu bar in the top part of the tool (Figure 19).

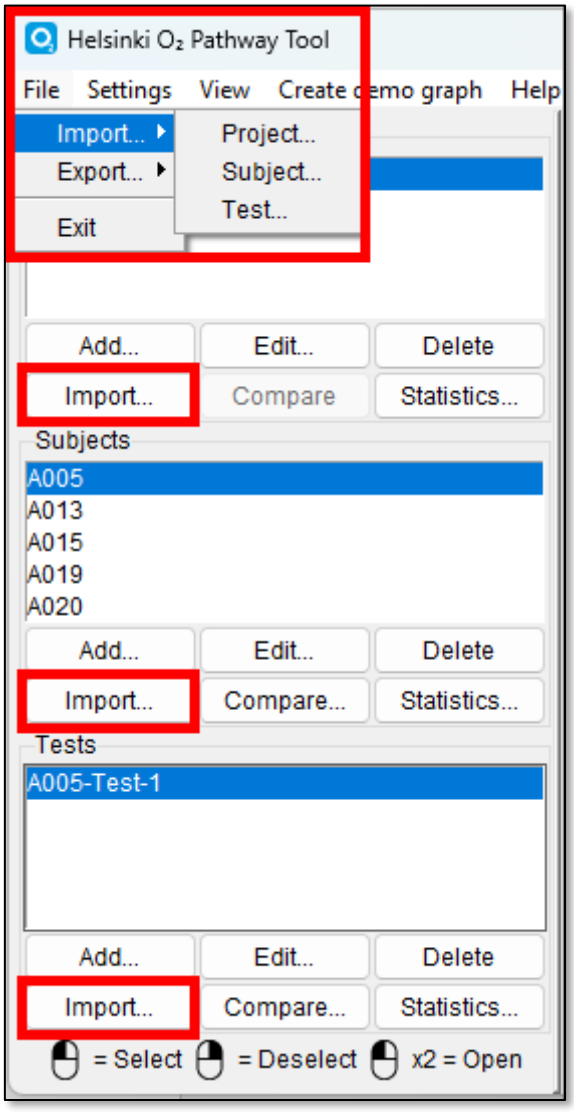
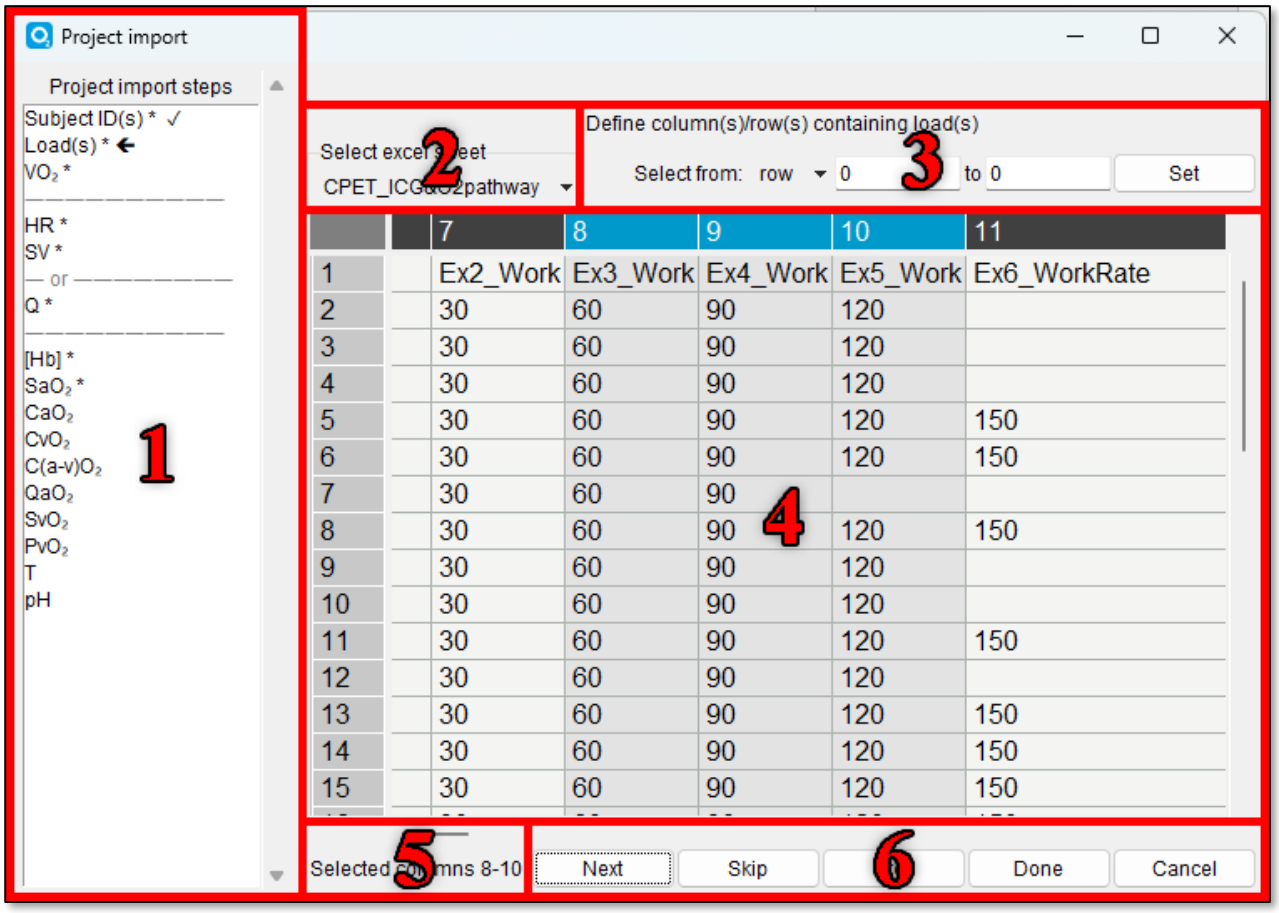


Figure 19 – Different locations where the data import wizard can be started.

Once the wizard is launched it will ask you to point out the file you want to import. After selection of the file to be imported, the wizard processes the file and opens it in a new window (Figure 20). The main idea behind the data import wizard is to enable you to tell the tool how you have structured your data. This is achieved by telling the tool where the wanted information is located by highlighting rows/columns parameter by parameter.

The import wizard is constructed with the following sections:

1. List of import steps:
2. Datasheet selection drop-down menu
3. Mass selection tools
4. Data table
5. Current selection indicator
6. Navigation buttons



	7	8	9	10	11
1	Ex2_Work	Ex3_Work	Ex4_Work	Ex5_Work	Ex6_WorkRate
2	30	60	90	120	
3	30	60	90	120	
4	30	60	90	120	
5	30	60	90	120	150
6	30	60	90	120	150
7	30	60	90		
8	30	60	90	120	150
9	30	60	90	120	
10	30	60	90	120	
11	30	60	90	120	150
12	30	60	90	120	
13	30	60	90	120	150
14	30	60	90	120	150
15	30	60	90	120	150

Figure 20 – The data import wizard is constructed of six main components: the import step list (1), the datasheet selection menu (2), the mass selection tool (3), the data table (4), the current selection indicator (5) and the navigation buttons (6).

7.1 List of import steps

Import step list shows you the steps that are included in the data import wizard. You can advance in the list by the navigation buttons or by clicking any list item. The current location in the list is indicated by a left pointing arrow. Successfully imported parameters are indicated by a check mark. If you have mistakenly imported wrong data, you can return to the parameter and input correct data at any time. You do not have to go through all the parameters if you have data only for specific parameters. You can confirm the import by clicking the "**Done**" button or close the wizard by clicking the "**Cancel**" button (Figure 20). The data import wizard is designed so that the following information is mandatory:

1. ID
2. Load

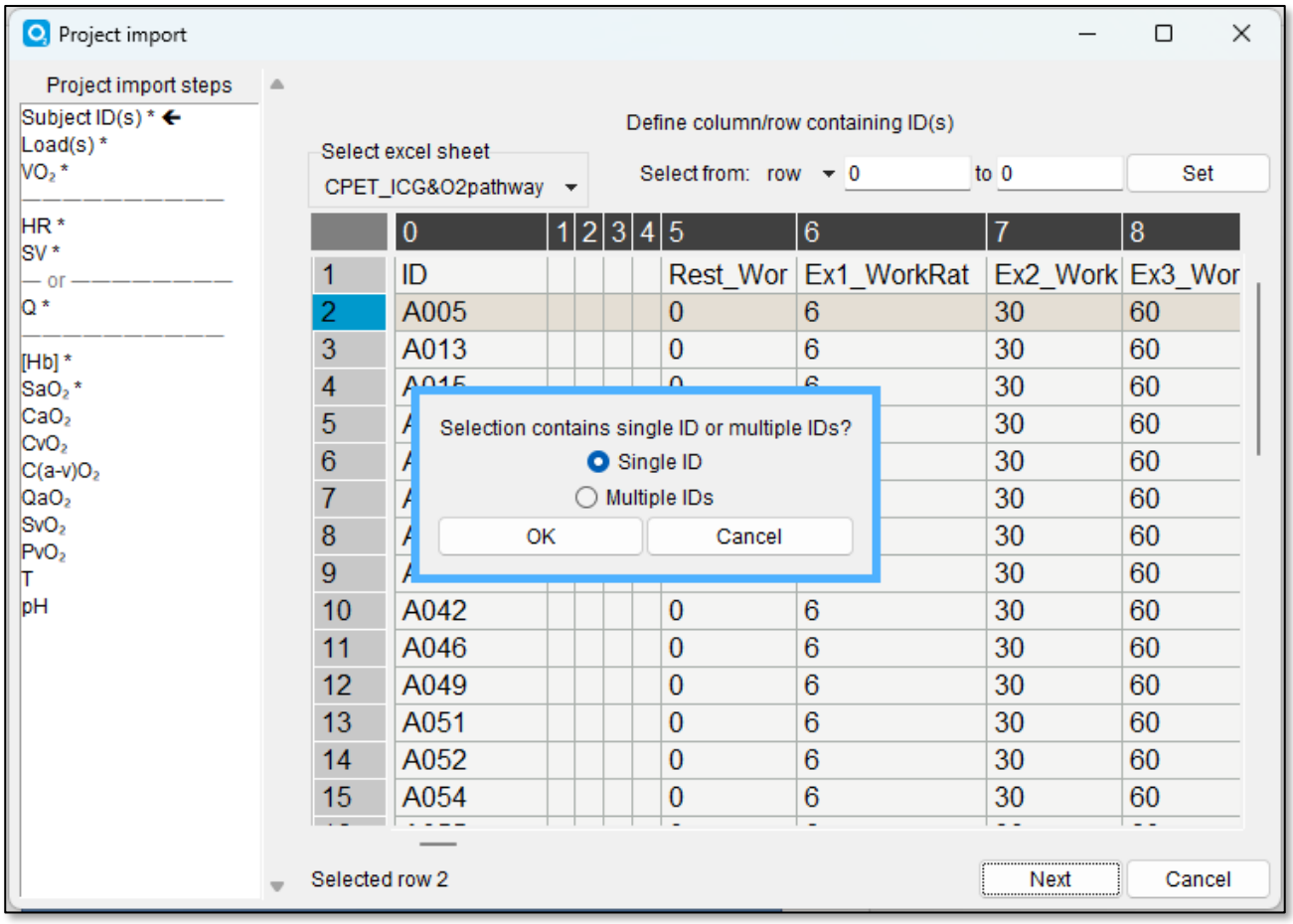
ID(s) is used as identification purposes and as the name of the created event(s). Load(s) is the workload of an exercise stress test to which the later imported data is assigned. Other important parameters are marked with an asterisk and include:

1. $\dot{V}O_2$
2. HR & SV or $\dot{Q}$
3. [Hb]
4. SaO_2

However, some of the parameters can be calculated with the help of other parameters, so there might be a way to use the tool if some of the parameters listed above are missing. To check which parameters can be calculated with the help of other parameters, please refer to Table 1.

To use the data import wizard, you must start from and successfully import at least steps "**ID**" and "**Load**". Without these parameters the tool is not able to create subjects and tests successfully and data importing errors might occur.

If only one row/column is selected for the "**ID**" parameter, a pop-up window appears (Figure 21). The purpose of this pop-up window is to determine the shape of your data. Information about the shape of the data is crucial for the importer to work as intended, so this question is mandatory and if cancelled, the data cannot be imported. If multiple rows/columns are selected, the shape of the data is automatically determined.



	0	1	2	3	4	5	6	7	8
1	ID					Rest_Wor	Ex1_WorkRat	Ex2_Work	Ex3_Wor
2	A005					0	6	30	60
3	A013					0	6	30	60
4	A015					0	6	30	60
5	A							30	60
6	A							30	60
7	A							30	60
8	A							30	60
9	A							30	60
10	A042					0	6	30	60
11	A046					0	6	30	60
12	A049					0	6	30	60
13	A051					0	6	30	60
14	A052					0	6	30	60
15	A054					0	6	30	60

Figure 21 – The pop-up window asks if the selection contains single or multiple IDs. The answer helps determine the shape of the data.

7.2 Sheet selection menu

If the file you want to import data from contains more than one sheet, they are listed in the sheet selection drop-down menu. The wizard opens the first sheet by default. You can import data from different sheets, but make sure the data in different sheets is shaped the same way. The data is fetched based on the row(s) / column(s) listed in the "**Load**"-phase and if the shape of the data is determined incorrectly, importing errors might occur.

7.3 Mass selection

If your data contains so many rows/columns that it is very laborious to make selections yourself, you can use the mass selection tool. The working principle of the mass selection tool is that you set the first and the last row/column you want to be selected and the tool makes the selection for you. To use mass selection tool, first select if you are selecting rows or columns from the drop-down menu, second set the start row/column to start the selection from, third set the last row/column you want to be selected, fourth click the "**Set**" button to select all the rows/columns between the start row/column and end row/column.

7.4 Data table

Data table is the HO_2PT's copy of the imported file. It contains the same information as the imported file. You can select rows and columns by left clicking the index bars shown in the picture below (Figure 22).

	5	6	7	8	9	10	11	12
1	Rest_Wor	Ex1_WorkRat	Ex2_Work	Ex3_Work	Ex4_Work	Ex5_Work	Ex6_WorkRate	Ex7_Work
2	0	6	30	60	90	120		
3	0	6	30	60	90	120		
4	0	6	30	60	90	120		
5	0	6	30	60	90	120	150	
6	0	6	30	60	90	120	150	
7	0	6	30	60	90			
8	0	6	30	60	90	120	150	
9	0	6	30	60	90	120		
10	0	6	30	60	90	120		
11	0	6	30	60	90	120	150	
12	0	6	30	60	90	120		
13	0	6	30	60	90	120	150	
14	0	6	30	60	90	120	150	
15	0	6	30	60	90	120	150	180
16	0	6	30	60	90	120	150	180
17	0	6	30	60	90	120		

Figure 22 - The data table is a copy of the imported file. Selection of rows or columns can be done in the index bars marked by red rectangles. In the figure columns 6,7 and 8 are currently selected which is indicated by highlighted column indexes and cells.

There are multiple ways you can make your selection:

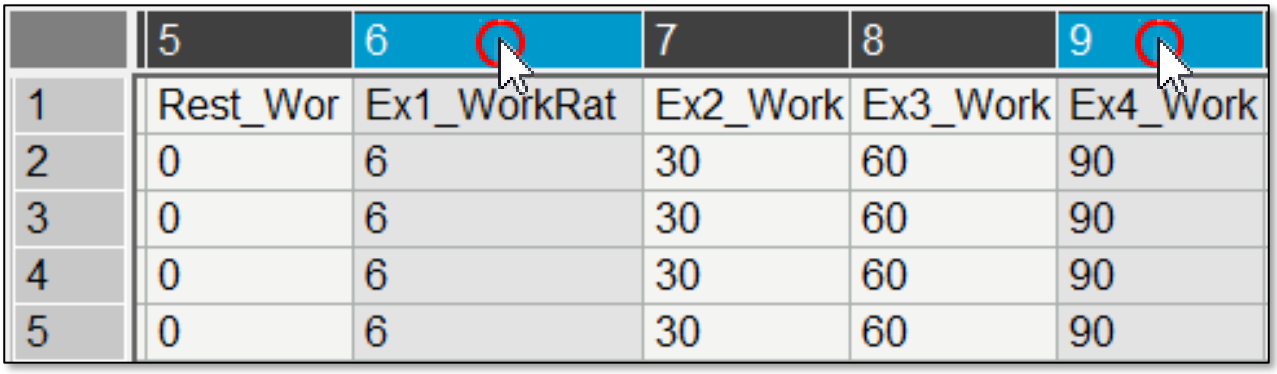
1. Left click a single row/column index
2. Hold down the CTRL button and left click on wanted indexes to select multiple rows/columns (Figure 23)
3. Left click the start row/column index and while holding down the SHIFT button, left click the end row/column index to select multiple rows/columns (Figure 24)
4. While holding left click, move the mouse over wanted row/column indexes to select multiple rows/columns (Figure 25)
5. Right clicking anywhere on the datatable to deselect everything

These functionalities enable you to freely select the wanted rows/columns to import data from.

Examples

Select data from columns 6 and 9:

1. Left click on the index of column 6.
2. Hold down the CTRL button and left click on the index of column 9.

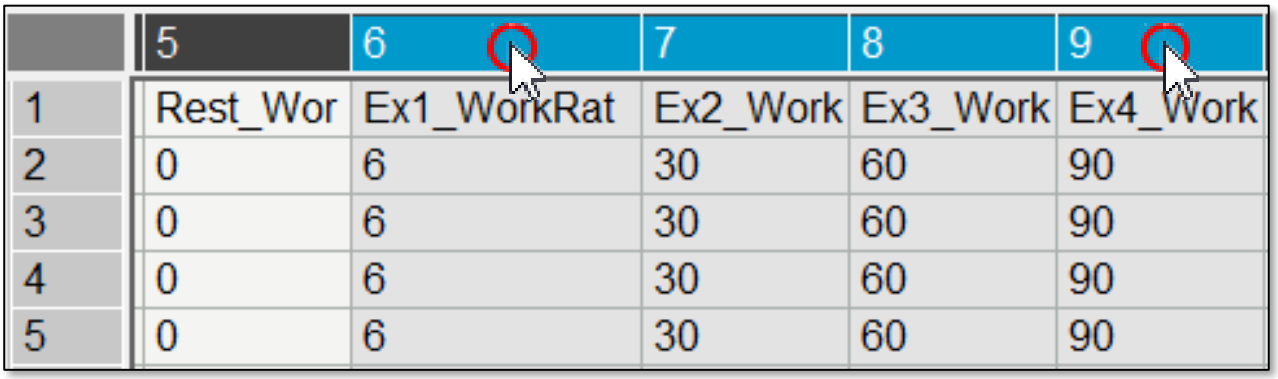


	5	6	7	8	9
1	Rest_Wor	Ex1_WorkRat	Ex2_Work	Ex3_Work	Ex4_Work
2	0	6	30	60	90
3	0	6	30	60	90
4	0	6	30	60	90
5	0	6	30	60	90

Figure 23 – Multiple selection by CTRL button.

Select data from columns 6 to 9:

1. Left click on the index of column 6.
2. Hold down the SHIFT button and left click on the index of column 9.

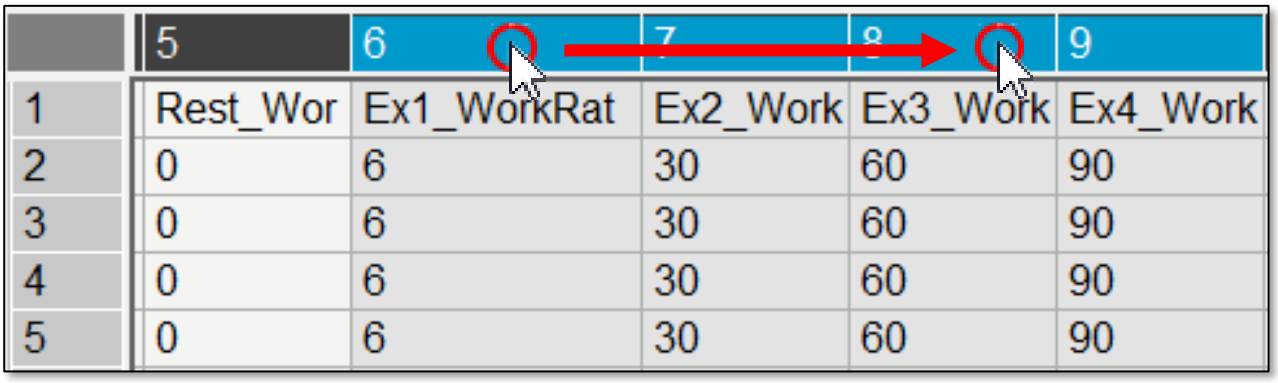


	5	6	7	8	9
1	Rest_Wor	Ex1_WorkRat	Ex2_Work	Ex3_Work	Ex4_Work
2	0	6	30	60	90
3	0	6	30	60	90
4	0	6	30	60	90
5	0	6	30	60	90

Figure 24 – Multiple selection by SHIFT button.

Select data from columns 6 to 9 alternative:

1. Left click on the index of column 6.
2. Hold down left click and move cursor on the index of column 9.



	5	6	7	8	9
1	Rest_Wor	Ex1_WorkRat	Ex2_Work	Ex3_Work	Ex4_Work
2	0	6	30	60	90
3	0	6	30	60	90
4	0	6	30	60	90
5	0	6	30	60	90

Figure 25 – Multiple selection by cursor motion

7.4.1 Current selection indicator

The current selection indicator shows you the current selection (Figure 26). You can ensure from the indicator that the tool has selected the wanted row(s) / column(s) after for example the mass selection tool.

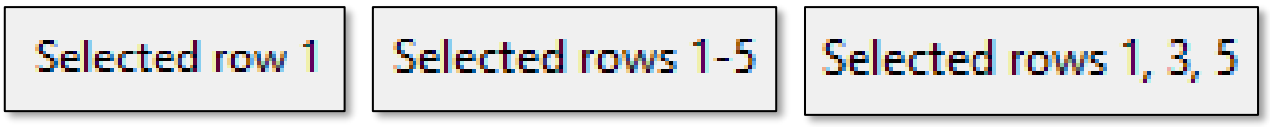


Figure 26 – The current selection is shown in written form.

7.4.2 Navigation buttons

Navigation buttons (Figure 27) act as a secondary way to control the data importing process. You can proceed or return to a previous phase by clicking the "**Next**" and "**Prev**" buttons. If you do not have any data for the current phase's parameter, you can move to the next phase by clicking the "**Skip**" button. After you have input all the data you intended, you can any time finish the process by clicking the "**Done**" button. You can as well cancel the importing process at any time by clicking the "**Cancel**" button.

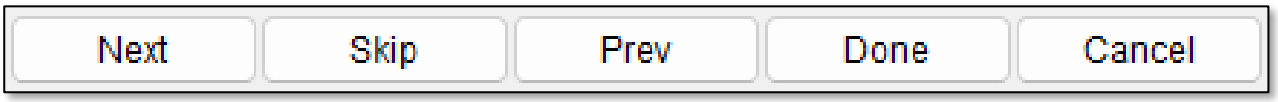


Figure 27 – Full set of navigation buttons. When the data import wizard is launched the only visible buttons are "Next" and "Cancel". "Skip" button's text is changed to "Use default values" when importin pH and T values.

7.5 Import using template files

There are three individual template files for importing projects, subjects and tests, that can be found in the "**../templates**" directory. When using the template files, you do not have to use the data importing wizard since data from the template files is imported automatically. If you do not have already collected data to a spreadsheet file and intend to use the HO_2PT, try collecting or transferring the data to a suitable template file to reduce the steps needed for the O_2 pathway analysis. Instructions on how to use the template files can be found in the template files itself.

8 Exporting data

There are four options for how to export data:

1. Exporting active project's content into a new datasheet file
2. Exporting active project's content into an imported file
3. Exporting only created content into a new datasheet file
4. Exporting only created content into an imported file

The HO_2PT does not override your data. Instead, it creates a copy of your imported file. The imported file is overridden only if you save results with the same file name as the imported file in the exporting process.

These options enable you to model the O_2 pathway projectwise or just for selected subjects or tests. The exporting options can be found from the "**File**" -> "**Export…**" menu in the main menu bar (Figure 28).

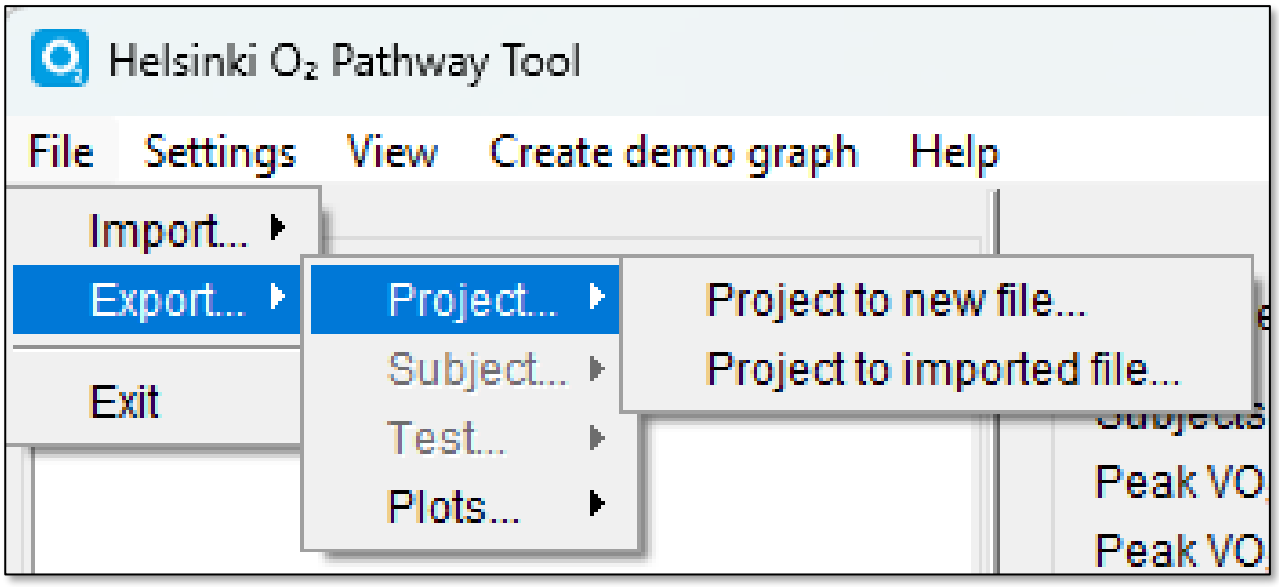


Figure 28 – Export options are located under the main menu bar's "File" and "Export" menu.

8.1 Exporting active project's content into a new datasheet file

If you have a large dataset and want to model the O_2 pathway for every subject in your dataset, you can let the tool do it for you. This way you do not have to create a figure for every single test by hand. The exporting process is straightforward:

1. Select the "**Project to new file…**" option from the "**File**" -> "**Export…**" menu.
2. Choose the parameters you want to export (Figure 29).
3. Click the "**Export**" button (Figure 29).
4. Define location and name for the file to be saved.

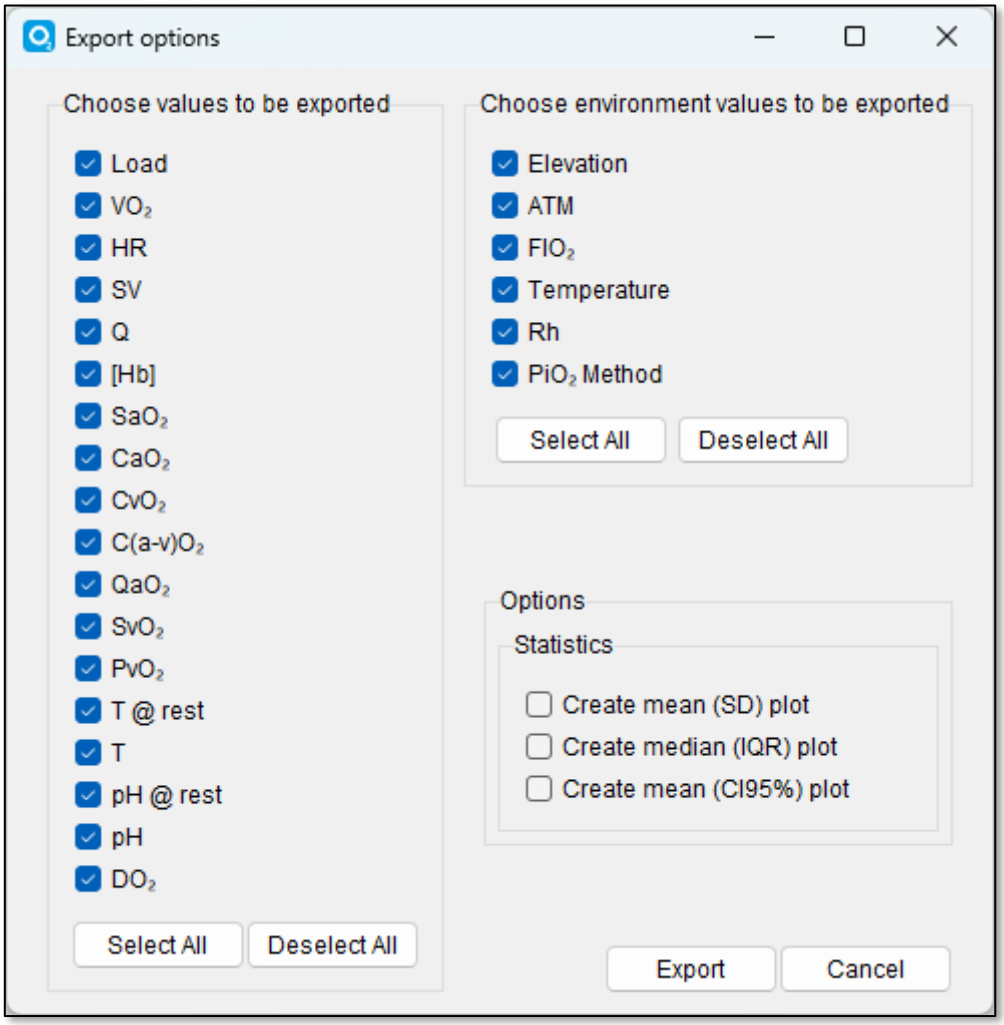


Figure 29 – You can select parameters to be exported by checking the checkboxes. By default, everything is exported.

Once the file is saved, the HO_2PT creates a new datasheet file (Figure 30) with the chosen parameters. The file contains separate sheets for every subject containing the quantitative and graphical results for every test. Statistics are also calculated during the exporting process and the results are saved in separate sheets in the file.

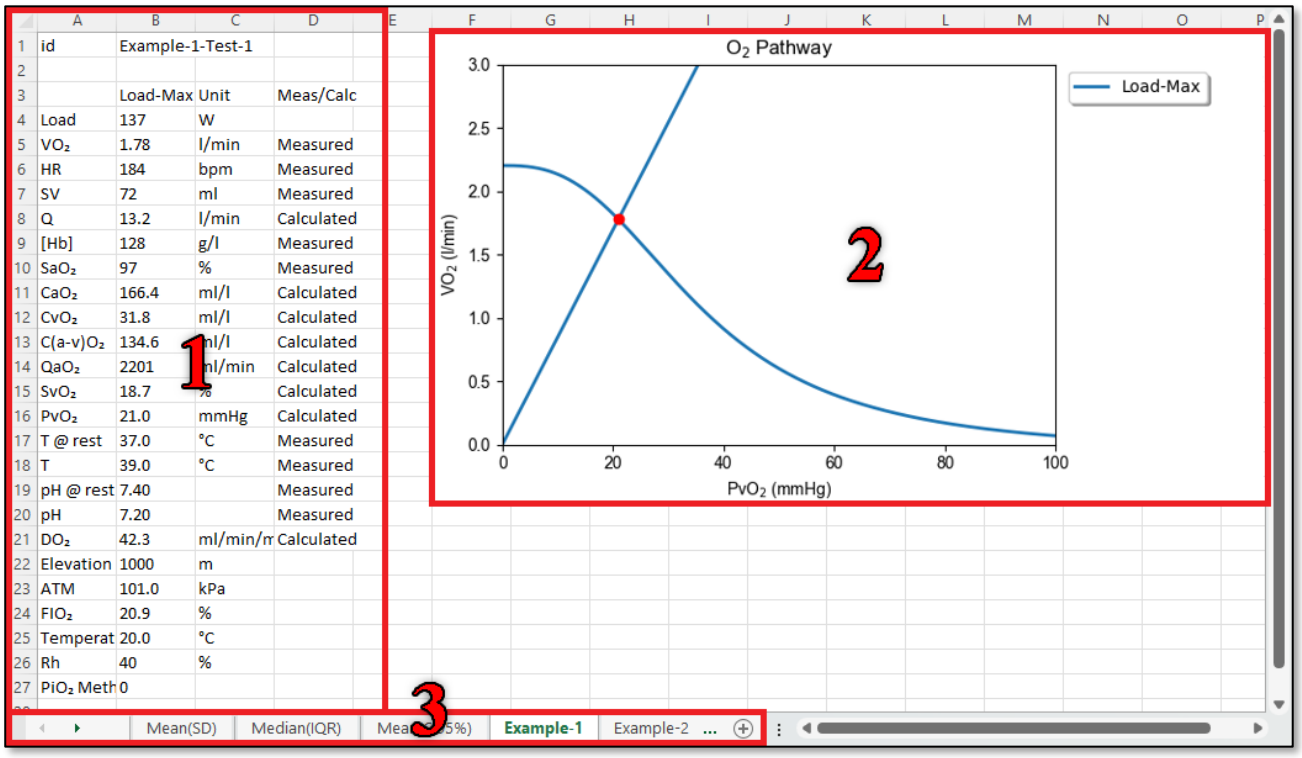


Figure 30 – Example of a datasheet file. Points of interest are marked with red rectangles: quantitative results of the modeling with loads on separate columns (1), graphical presentation of the data (2) and separated sheets named by the ID of the event (3).

8.2 Exporting active project's content into imported file

Exporting to the same file used in importing is also straightforward and follows the same steps as exporting to a new file:

1. Select the "**Project to new file…**" option from the "**File**" -> "**Export…**" menu.
2. Choose the parameters you want to export.
3. Choose the sheet you want to append the data to or create a new one (Figure 31).
4. Choose whether you want statistics graphs added to separate sheets.
5. Choose whether you want the tool to create a graph for every test on the project on a separate sheet.
6. Click the "**Export**" button (Figure 31).
7. Define location and name for the file to be saved.

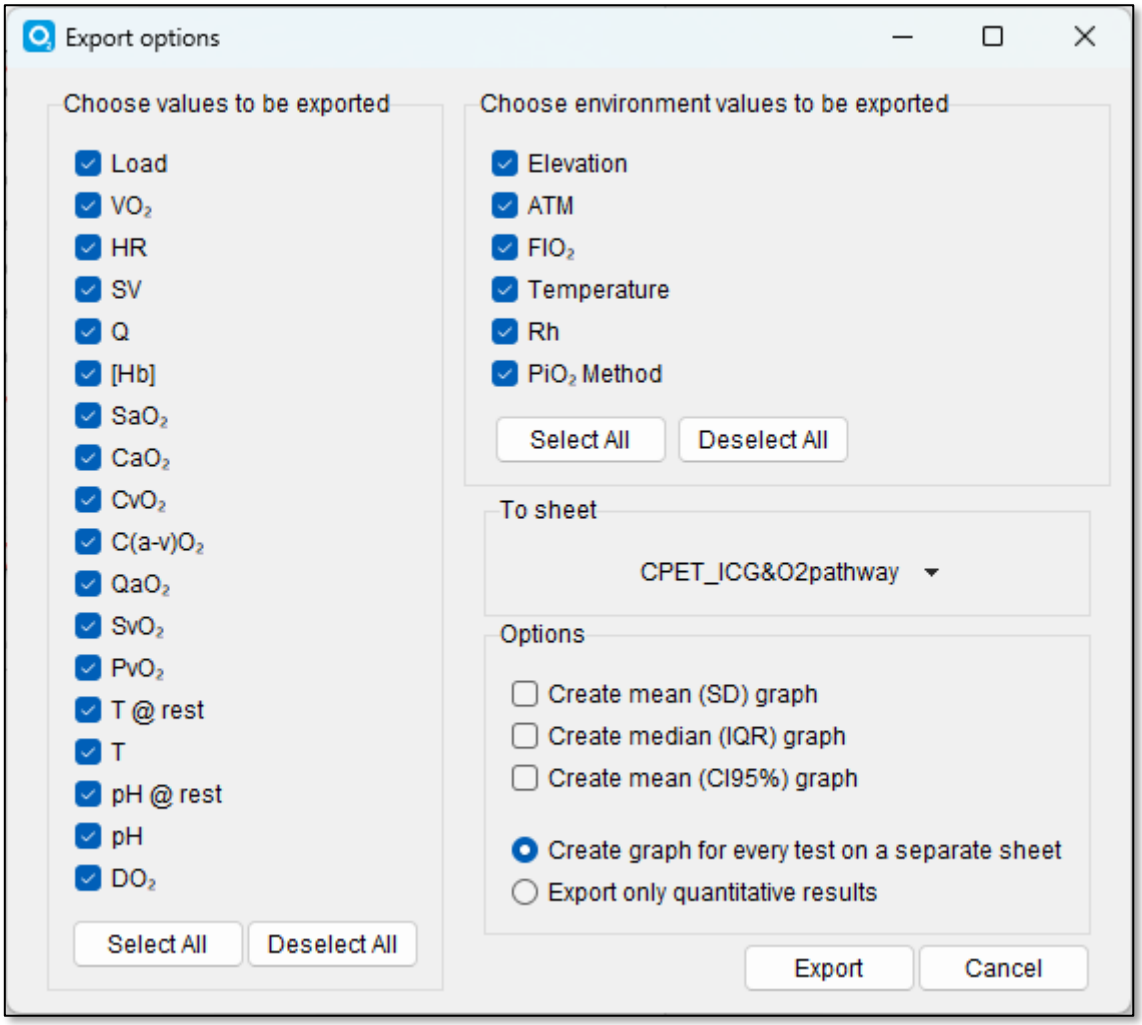


Figure 31 – Exporting to an existing file works the same way as to a new file with a difference of ability to select the sheet of the existing file you want to append the results to.

Once the file is saved, the HO_2PT creates a fresh copy of the file used to import the data from with the quantitative results appended to the selected sheet. Load indexes, used units, and measured/calculated values are stored in the name of the column/row.

In addition to appended data, statistics figures are added to their respective sheets as well as figures for every subject of the dataset in the sheet "**Plots**". Figures are saved next to the corresponding test's name for identification purposes.

8.3 Exporting only created content into a new datasheet file

When exporting only created content (Figure 32), the exporting process is basically the same as in exporting the whole project's content. The only difference is that in this case, only the figures you have created in the tool are to be exported.

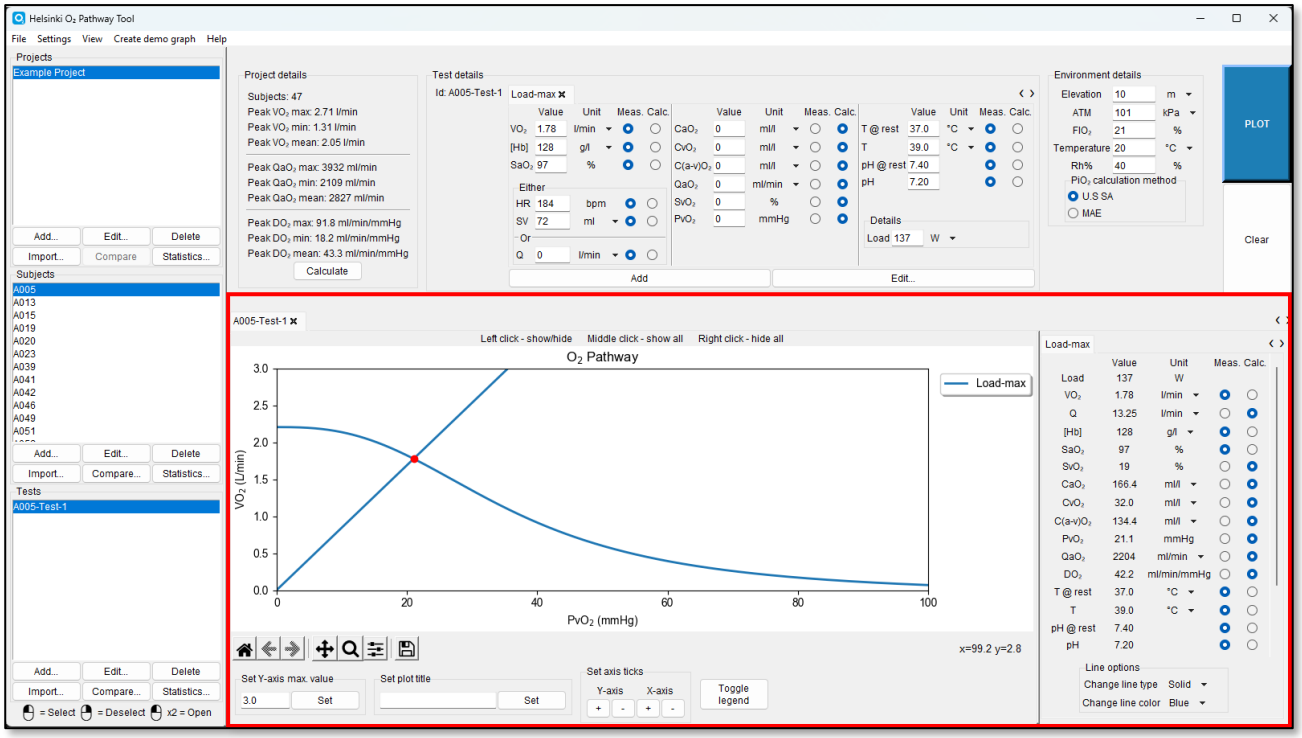


Figure 32 – Created content means the tabs in plot panel highlighted in the figure by red rectangle.

The exporting process works as follows:

1. Create figures as many as needed (instructions on how, please refer to this or this).
2. Select the "**Project to new file…**" option from the "**File**" -> "**Export**" menu.
3. Choose the parameters you want to export.
4. Click the "**Export**" button.
5. Define location and name for the file to be saved.

The saved excel file is constructed in the same way as exporting the whole project's content (Figure 30). Sheets are created for every test and selected parameters are saved load by load with figures shown next to the details.

8.4 Exporting only created content into imported file

When exporting only created content into the same file used to import data, the exporting process is very similar to exporting the whole project's content. The only difference is that the calculations and figures are appended as separate sheets to the imported file.

The exporting process works as follows:

1. Create figures as many as needed (instructions on how, please refer to this or this).
2. Select the "**Project to new file…**" option from the "**File**" -> "**Export**" menu.
3. Choose the parameters you want to export.
4. Click the "**Export**" button.
5. Define location and name for the file to be saved.

9 How to

Here is listed a few step-by-step examples to operate the HO_2PT.

9.1 Plot figure without imported data

1. Start the HO_2PT by running the "**HO2PT.exe**" file.
2. Click the "**Create demo graph**" option from the main menu bar (Figure 33).

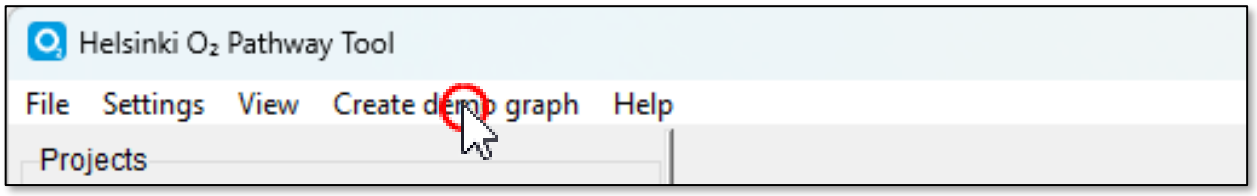


Figure 33

3. A demo figure is shown and the values used to create the figure are shown in the details panel (Figure 34).

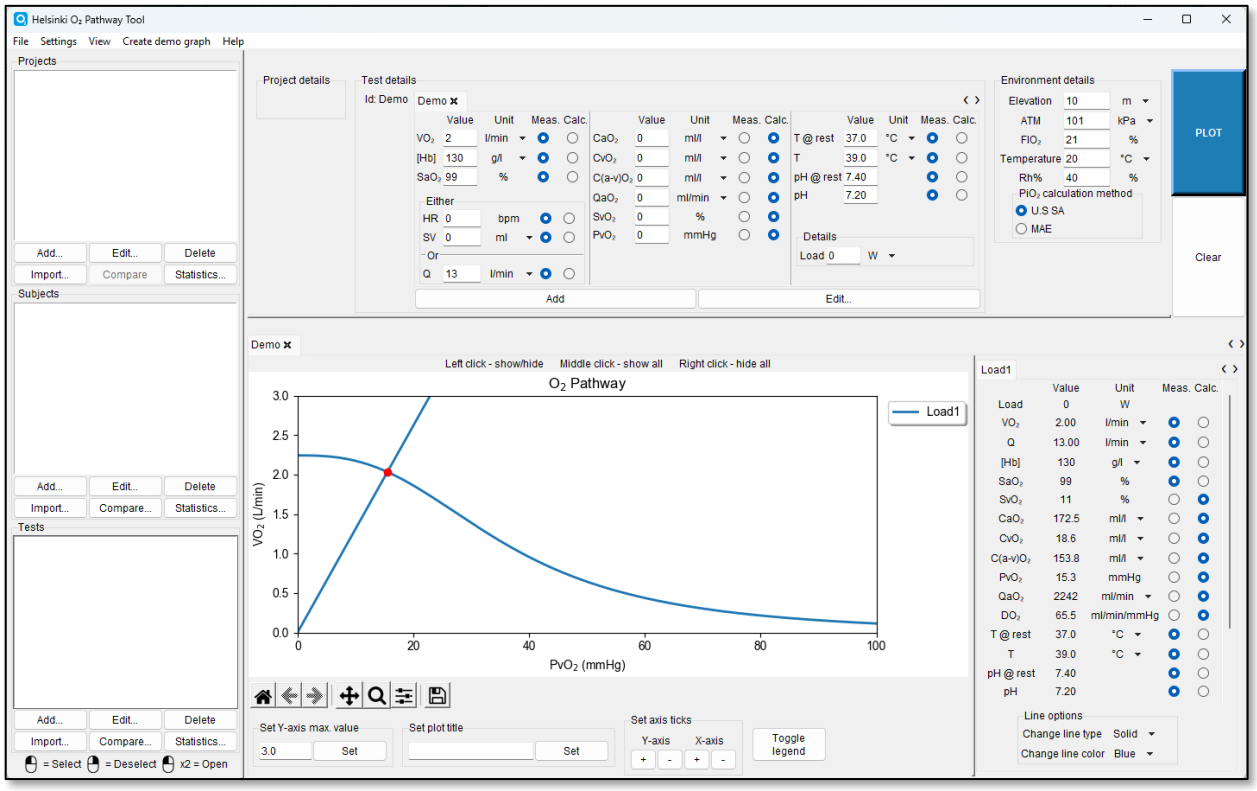


Figure 34

9.2 Plot figure with data entered by hand

1. Start the HO_2PT by running the "**HO2PT.exe**" file.
2. Click the "**Add…**" button in the side panels test module (Figure 35).
3. Click the "**Next**" button in the pop-up window (Figure 35).

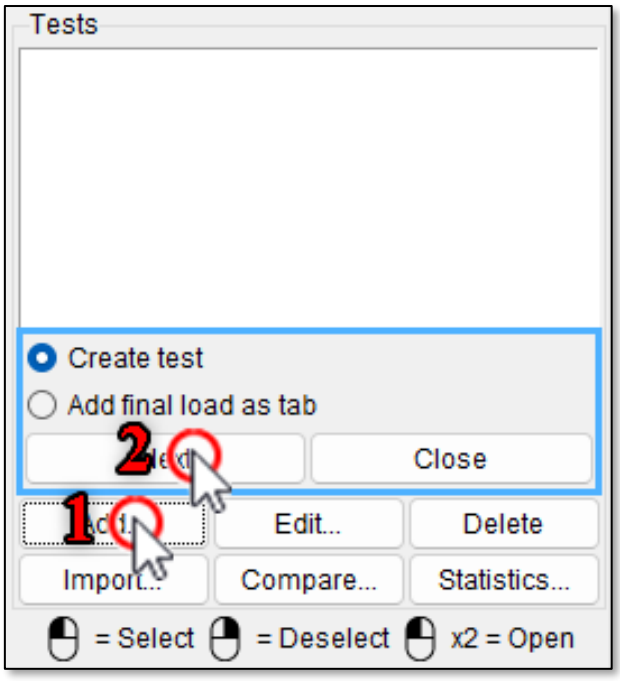


Figure 35

4. Enter values to the test details module (Figure 36).
   - The necessary values are grouped in the first column of the test details module.
   - You can still input other values as well. The values given are used in the modeling.

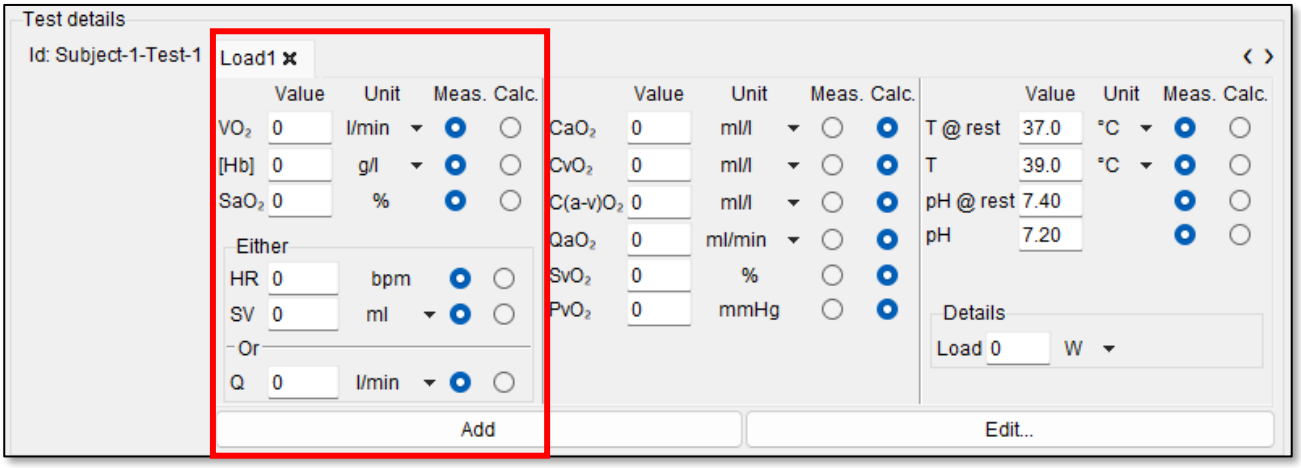


Figure 36

5. Click the "**Plot**" button (Figure 37).

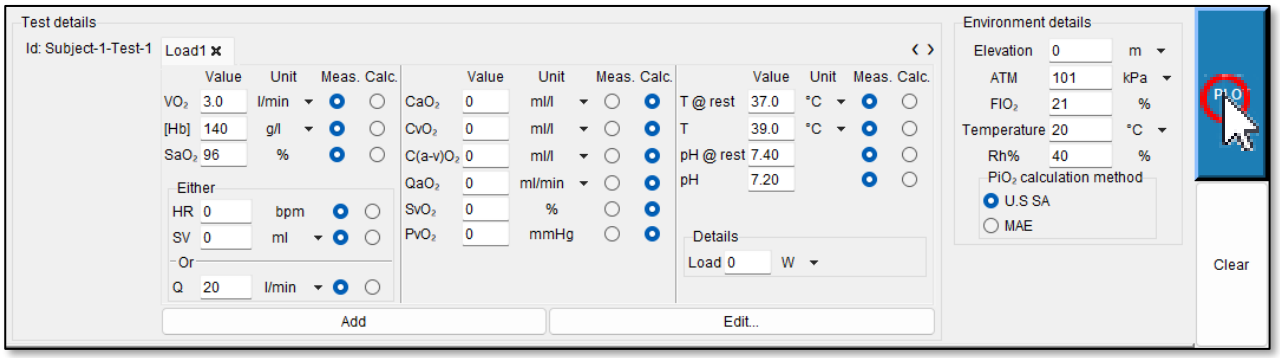


Figure 37

6. If the values given are valid, the figure is shown in the plot panel (Figure 38).

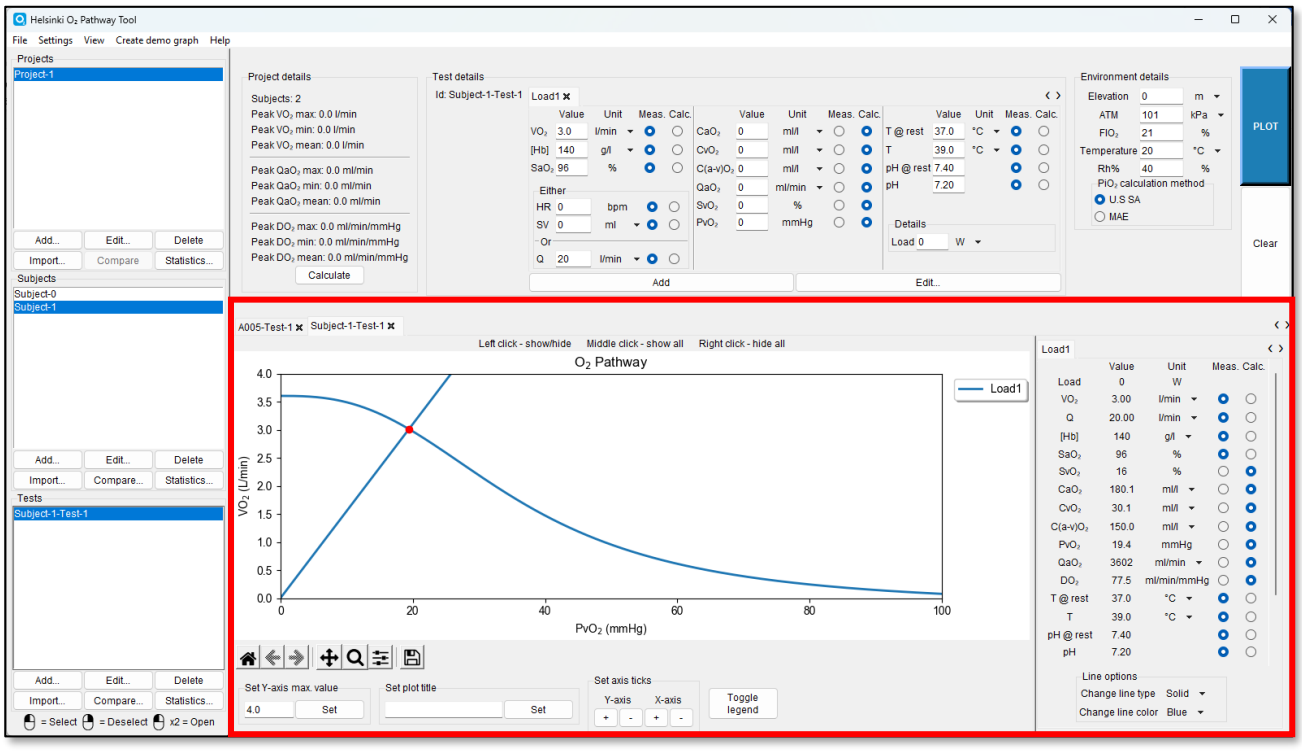


Figure 38

9.3 Plot a test from imported data

1. Start the HO_2PT by running the "**HO2PT.exe**" file.
2. Click the "**Import…**" button in the side panel's projects module (Figure 39).
3. Define the datasheet file (.xlsx-format) to be imported from in the pop-up window.

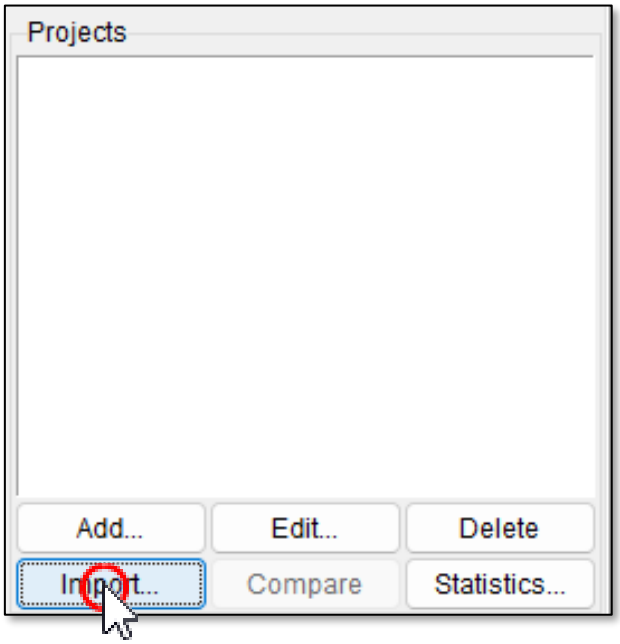


Figure 39

4. Data import wizard is started (Figure 40).

   (a) Click on the row/column containing the wanted ID.

   (b) Confirm the selection by clicking the "**Next**" button.

   (c) Confirm single ID input by clicking "**OK**" button.

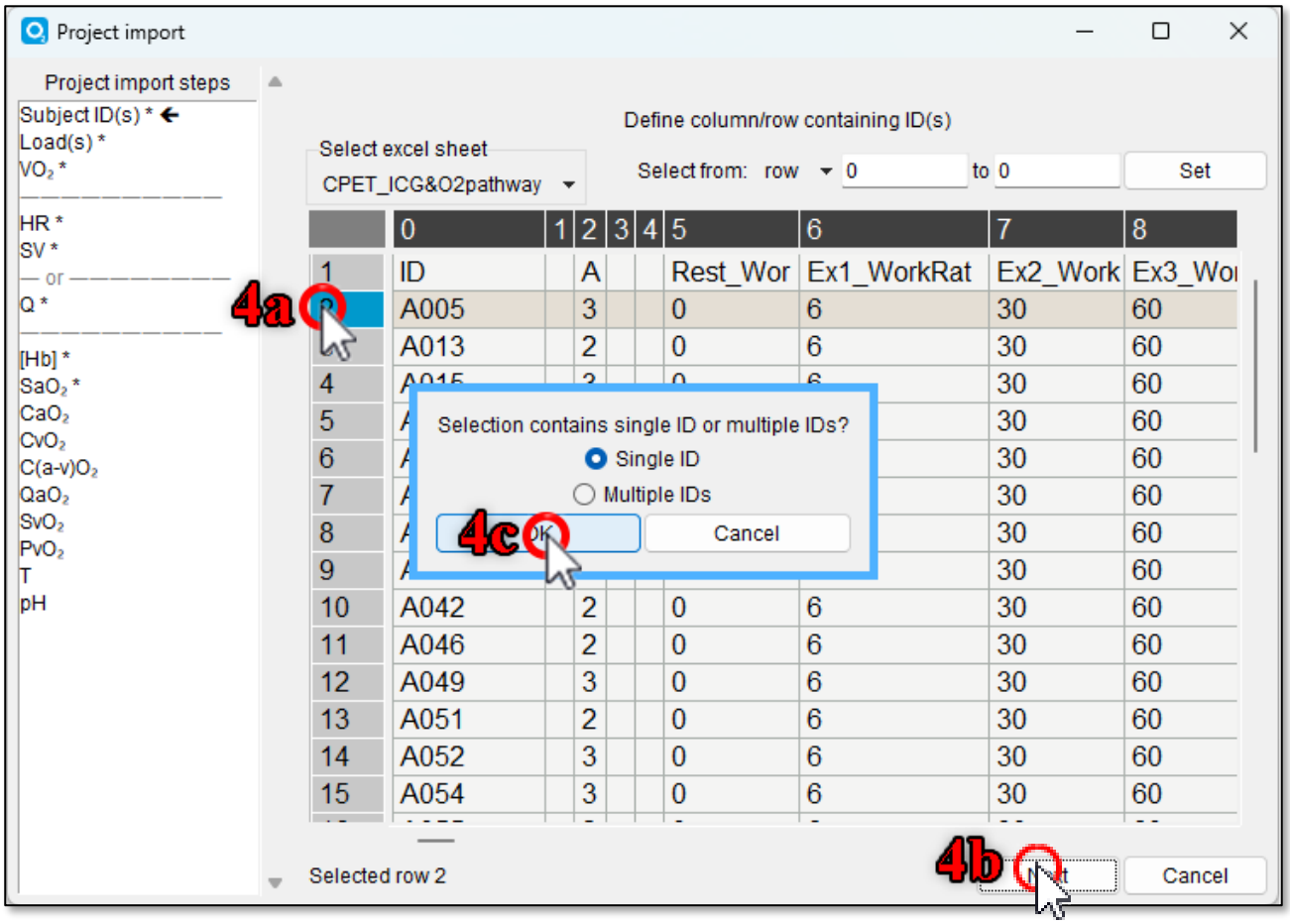


Figure 40

5. Define the loads (Figure 41).
   (a) Click the wanted index (different ways on how to do this are demonstrated here).
   (b) Click the "**Next**" button.
6. Repeat step 5 until SaO_2 and click the "**Done**" button.
   (a) You can move between phases by left clicking the parameter list.
   (b) You can skip a parameter by clicking the "**Skip**" button.

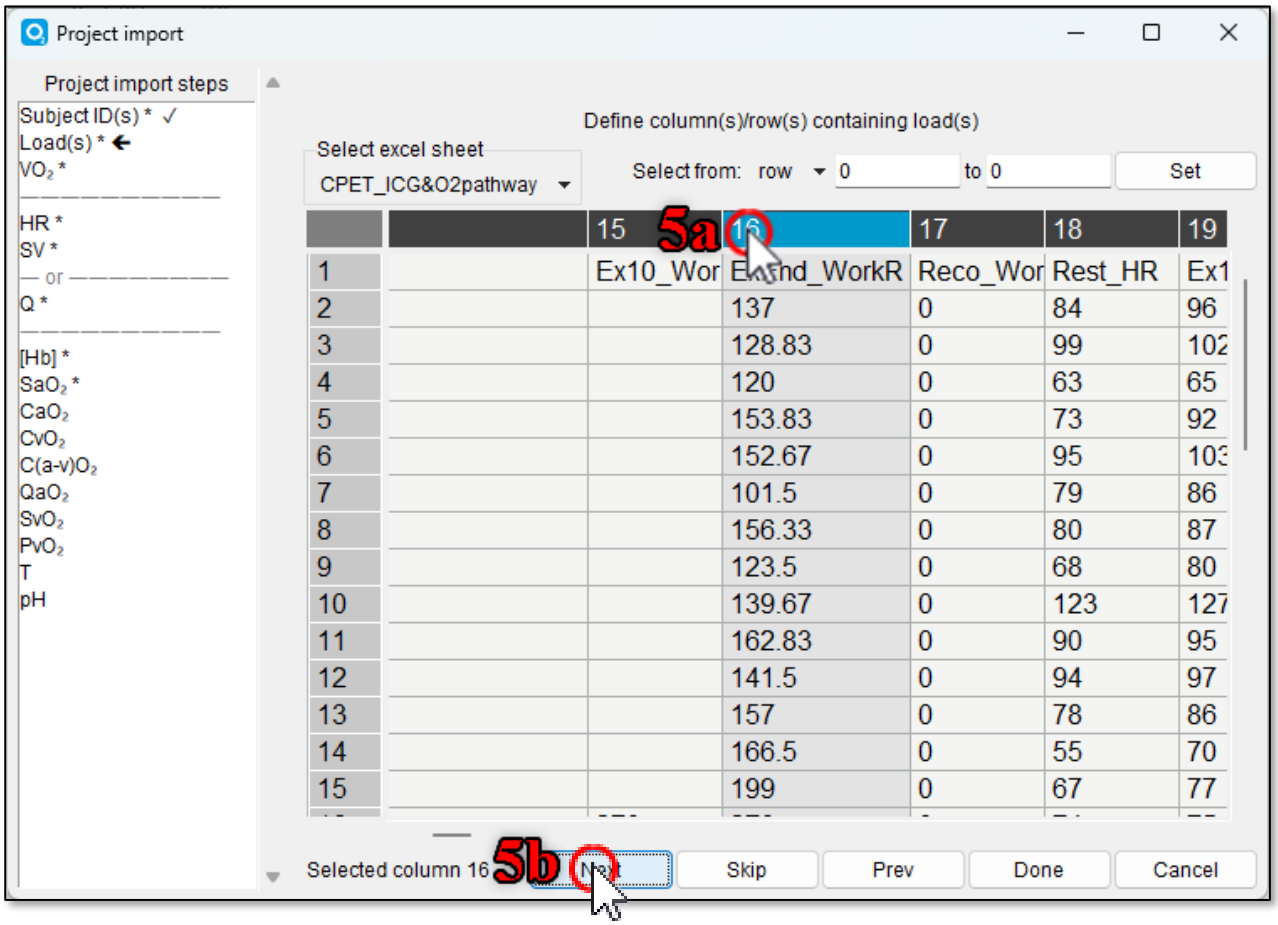


Figure 41

7. Click a subject to make it active in the side panel (Figure 42).
8. Double left click on a test in the side panel's test module (Figure 42).
9. The imported data is shown in the test details module (Figure 42).
10. Click the "**Plot**" button and the figure is created (Figure 42).

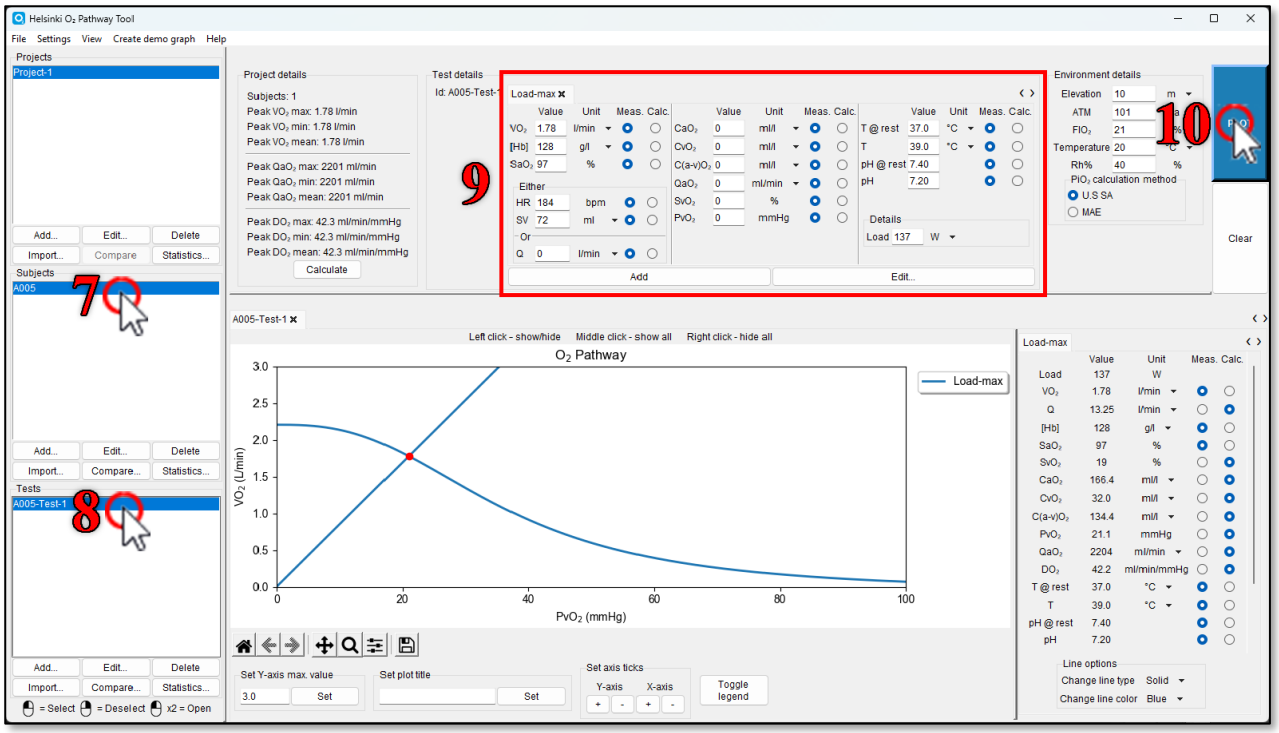


Figure 42

9.4 Plot comparison figure

1. Start the HO_2PT by running the "**HO2PT.exe**" file.
2. Import data (instructions on how are shown here).
3. Select the first subject for comparison by left clicking on it in the side panel's subject module (Figure 43).
4. While holding down the CTRL button, select the second subject for comparison by left clicking on it in the side panel's subject module (Figure 43).
5. Click the "**Compare…**" button (Figure 43).

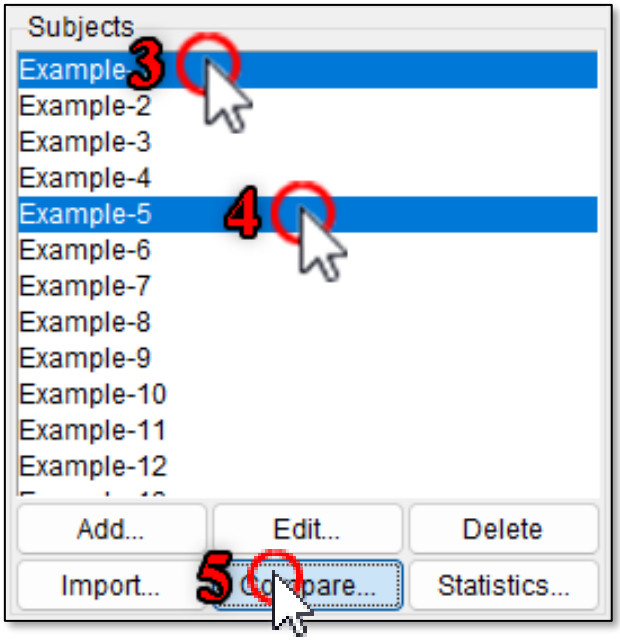


Figure 43

6. Select content for comparison and click the “**Compare**” button (Figure 44).

   (a) Test details module is updated with separate loads for every selected subject (Figure 44).

7. Click the “**Plot**” button (Figure 44).

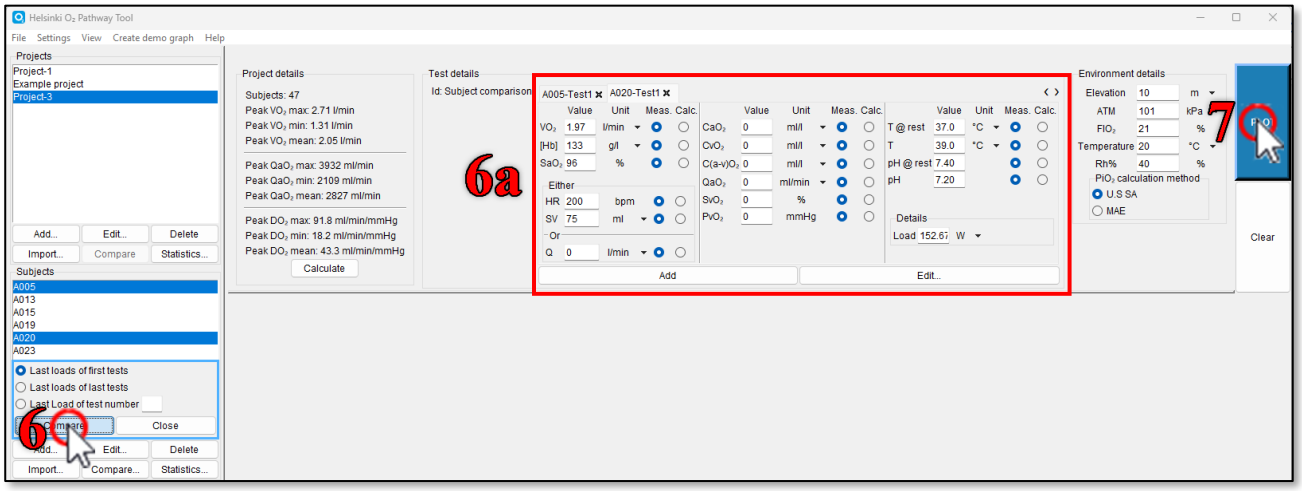


Figure 44

8. The comparison figure is shown in the plot panel (Figure 45).

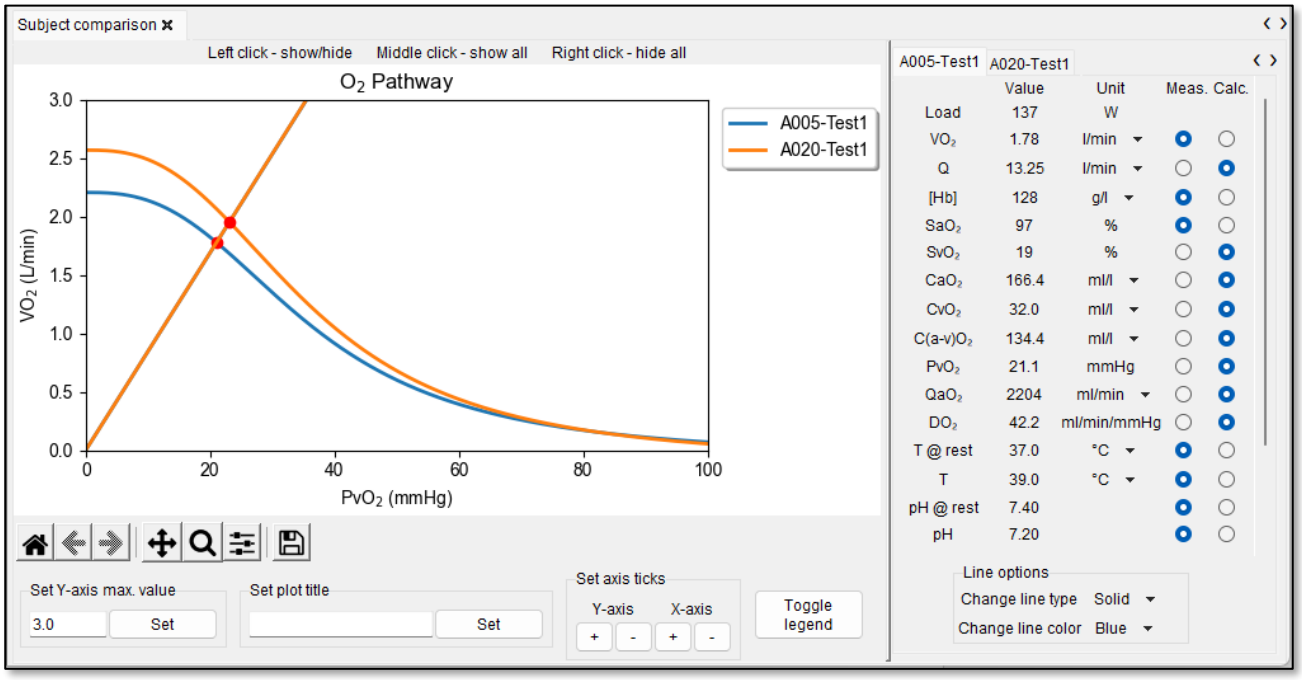


Figure 45

9.5 Plot statistics figure

1. Start the HO_2PT by running the "**HO2PT.exe**" file.
2. Import data (instructions on how are shown here).
3. Choose a project by left clicking on it in the side panel's project module (Figure 46).
4. Click the "**Statistics…**" button (Figure 46).
5. Select the statistical method to be used and click the "**Plot**" button (Figure 46).

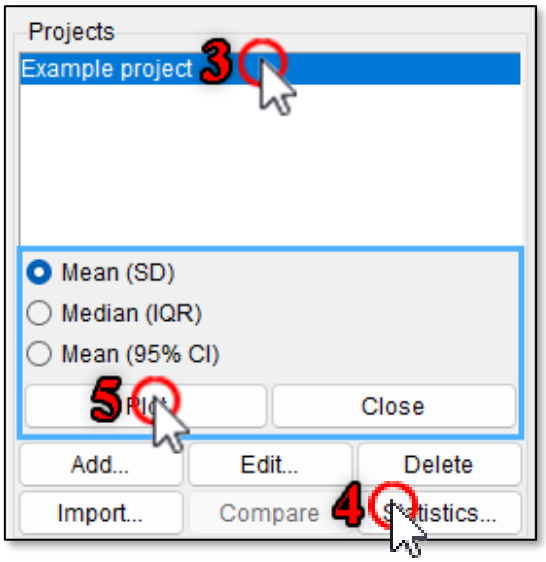


Figure 46

6. The statistics figure is shown in the plot panel and three load tabs have been created with the corresponding numerical values (Figure 47).

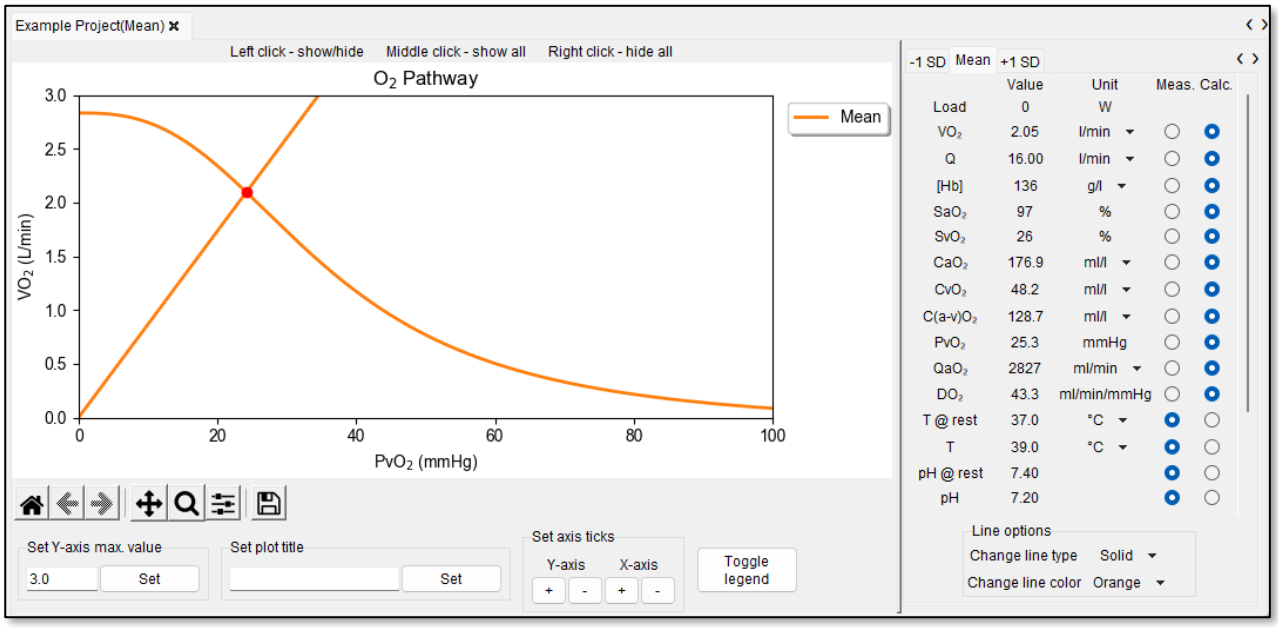


Figure 47

9.6 Export data to new file

1. Start the HO_2PT by running the "**HO2PT.exe**" file.
2. Import data (instructions on how are shown here).
3. Select the project you want to export from the side panel's project module.
4. Select an exporting method from the "**File**" menu in the main menu bar (Figure 48).

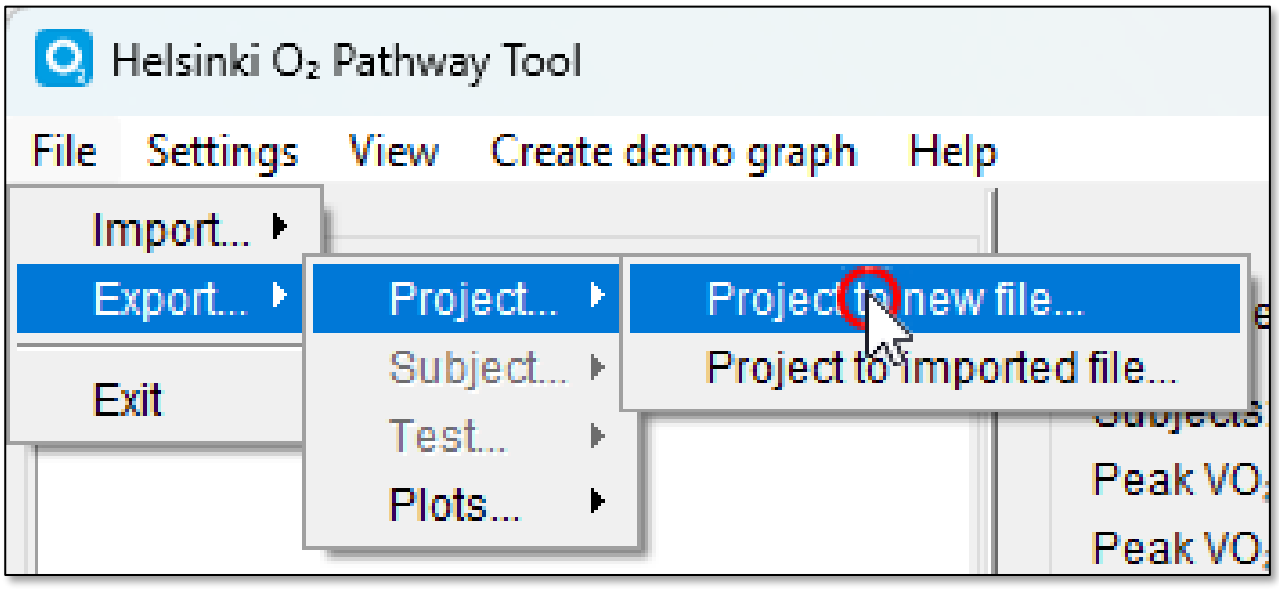


Figure 48

5. Select parameters to be exported (Figure 49).
   (a) You can deselect all by clicking the "**Deselect All**" button (Figure 49).
   (b) You can select all by clicking the "**Select All**" button (Figure 49).
6. Click the "**Export**" button (Figure 49).

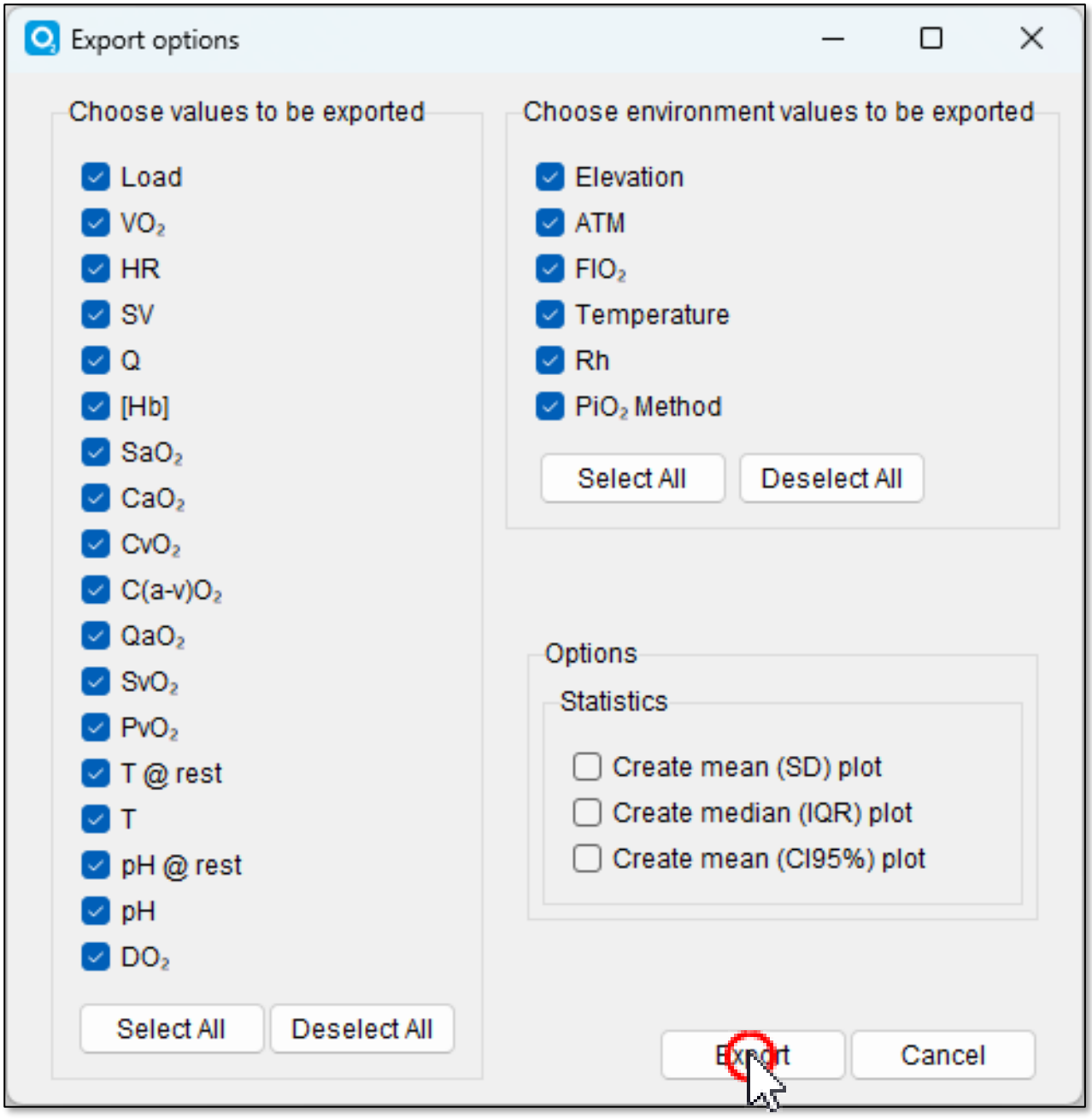


Figure 49

7. Wait for the file explorer pop-up window to appear and define the location of the export.
   (a) Name the file.
   (b) Click the "**Save**" button.
   (c) Successful export is indicated with a message on green background in the top part of the window (Figure 50).

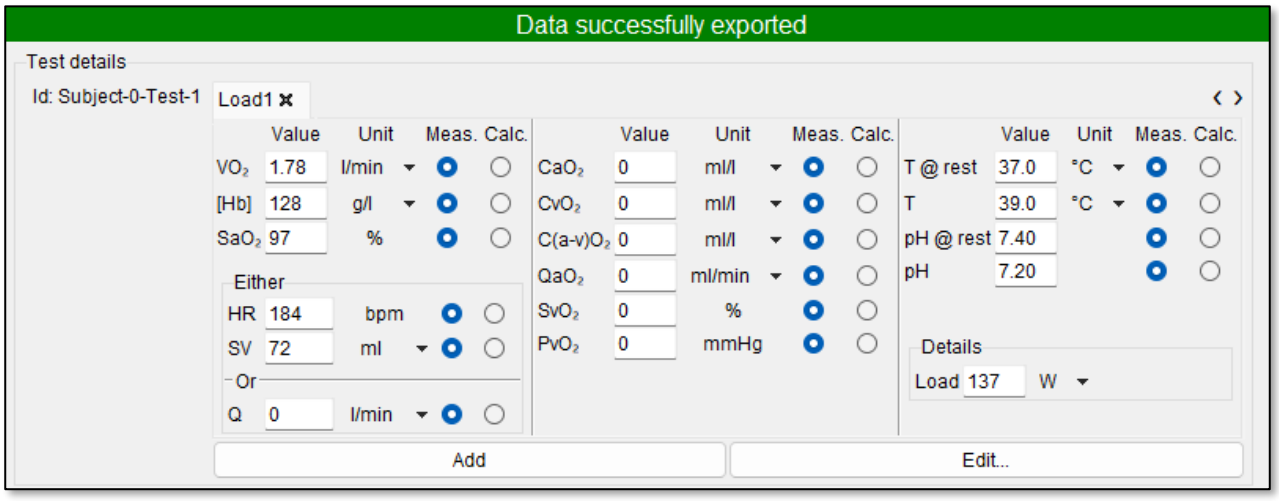


Figure 50

8. An excel file is created (Figure 51).

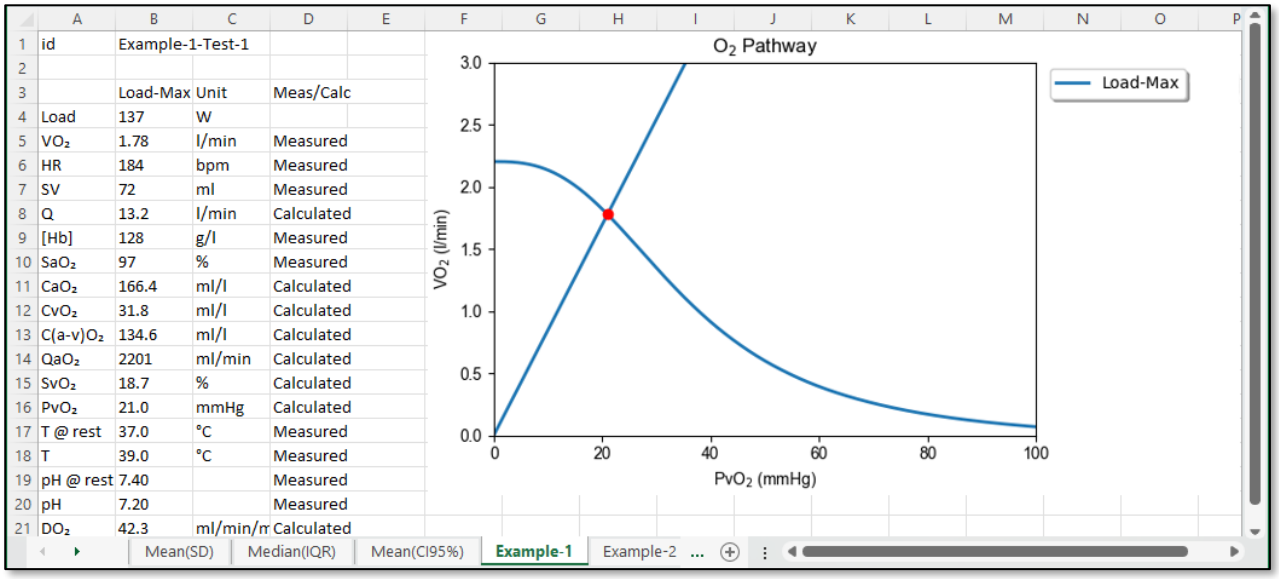


Figure 51

9.7 Export data to imported file

1. Start the HO_2PT by running the "**HO2PT.exe**"-file.
2. Import data (instructions on how are shown here).
3. Select the project you want to export from the side panel's project module.
4. Select an exporting method from the "**File**" menu in the main menu bar (Figure 52).

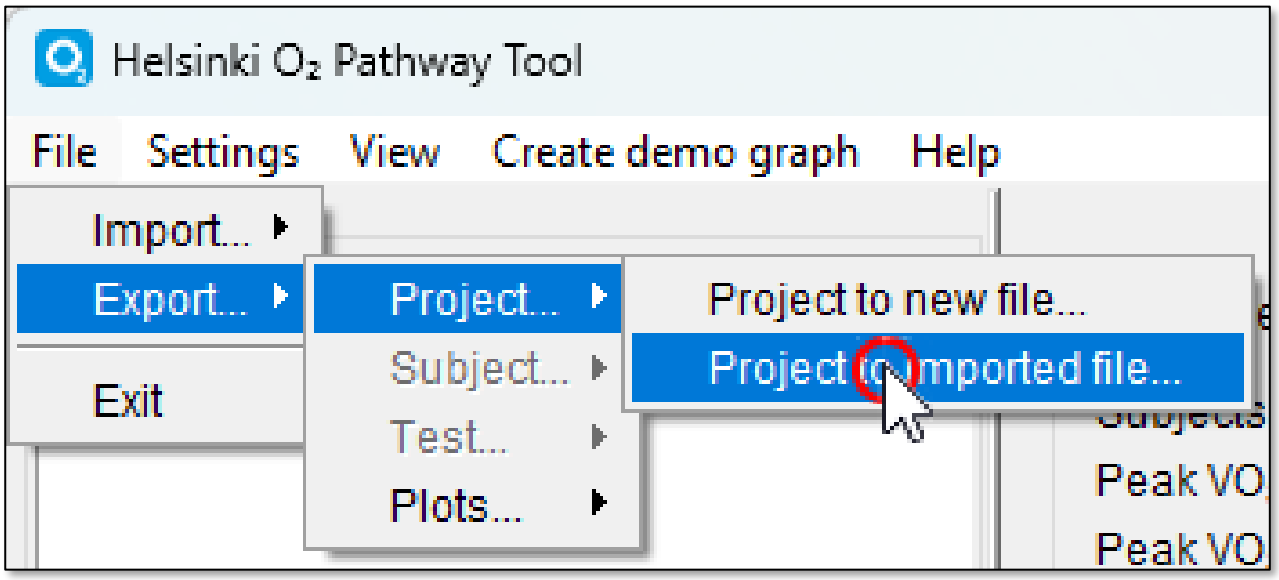


Figure 52

5. Select parameters to be exported (Figure 53).
   (a) You can deselect all by clicking the "**Deselect All**" button.
   (b) You can select all by clicking the "**Select All**" button.
6. Select the sheet you want to append the data to (Figure 53).
7. Click the "**Export**" button (Figure 53).

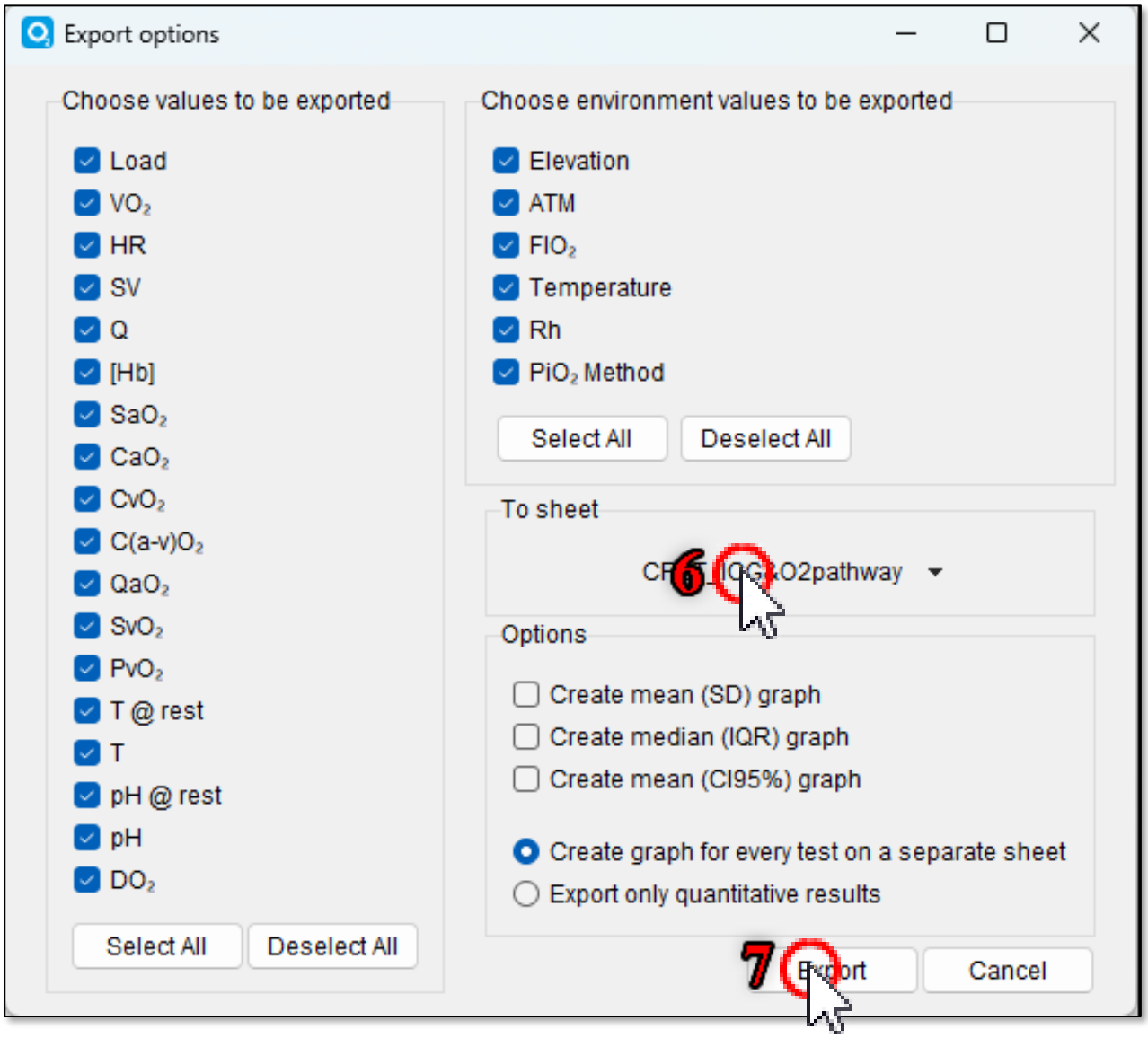


Figure 53

8. Wait for the file explorer pop-up window to appear and define the saving location for the exported file.

   (a) Name the file.

   (b) Click "**Save**" button.

9. Successful export is indicated with a green message in the top part of the window (Figure 54).

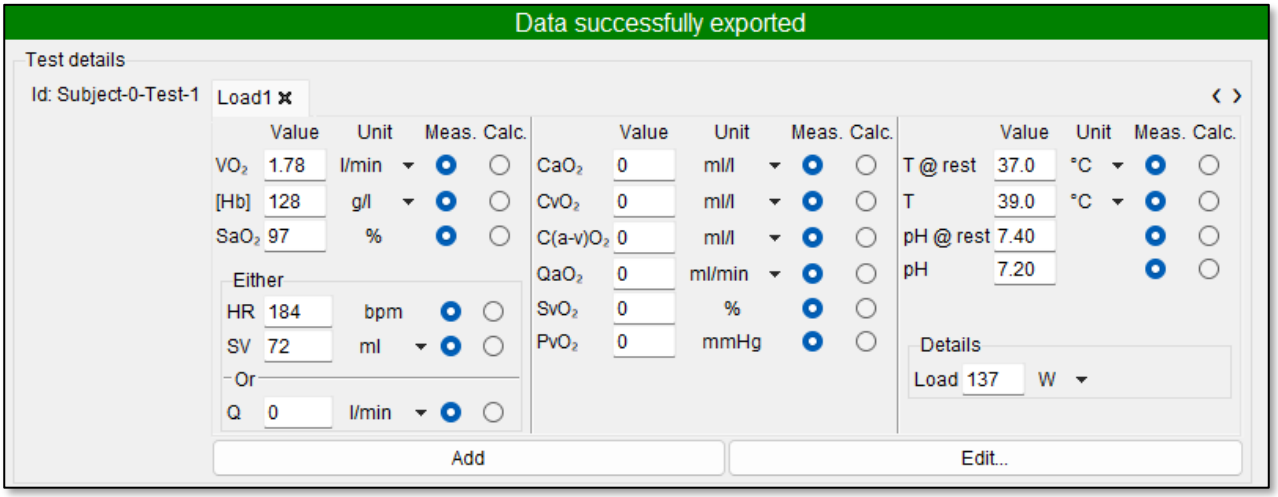
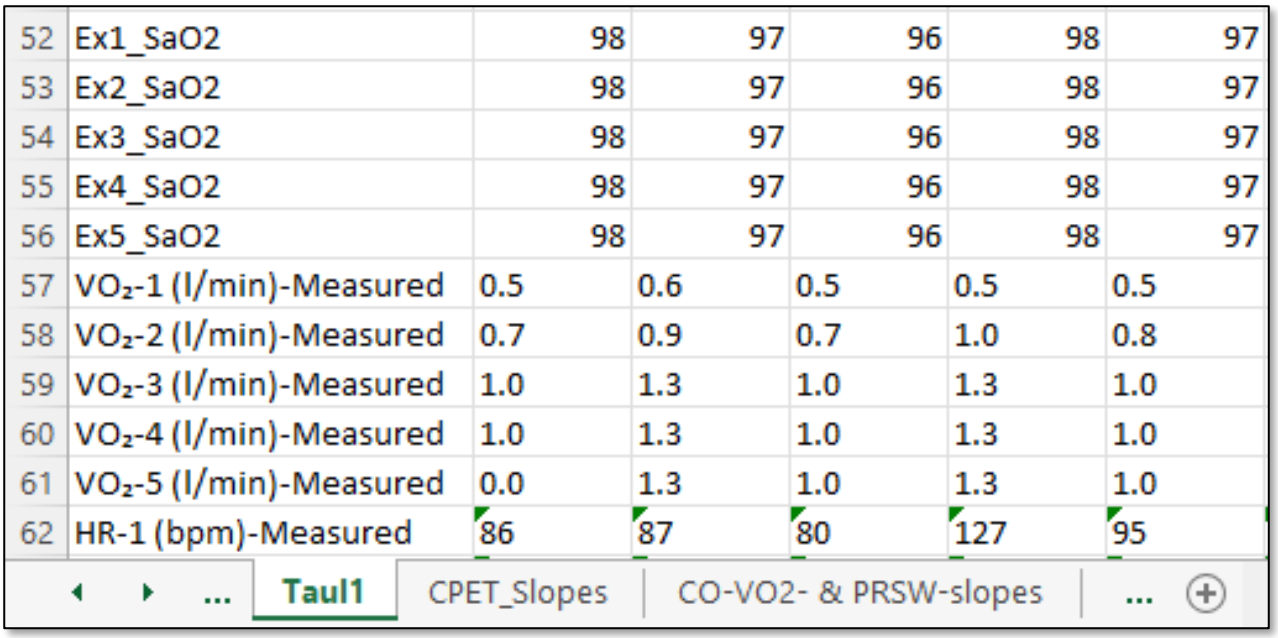


Figure 54

10. An excel file is created and the selected data is appended to the selected sheet (Figure 55).



52	Ex1_SaO2	98	97	96	98	97
53	Ex2_SaO2	98	97	96	98	97
54	Ex3_SaO2	98	97	96	98	97
55	Ex4_SaO2	98	97	96	98	97
56	Ex5_SaO2	98	97	96	98	97
57	VO_2-1 (l/min)-Measured	0.5	0.6	0.5	0.5	0.5
58	VO_2-2 (l/min)-Measured	0.7	0.9	0.7	1.0	0.8
59	VO_2-3 (l/min)-Measured	1.0	1.3	1.0	1.3	1.0
60	VO_2-4 (l/min)-Measured	1.0	1.3	1.0	1.3	1.0
61	VO_2-5 (l/min)-Measured	0.0	1.3	1.0	1.3	1.0
62	HR-1 (bpm)-Measured	86	87	80	127	95

Figure 55

10 Troubleshooting

10.1 Invalid values

'Invalid values. Please check the units….'. This error message appears, if the HO_2PT cannot model the O_2 pathway with the given values (Figure 56). This usually means that one of the following situations occurred:

1. Some parameter's unit is incorrect
2. Some parameter is missing and the modelling cannot be done

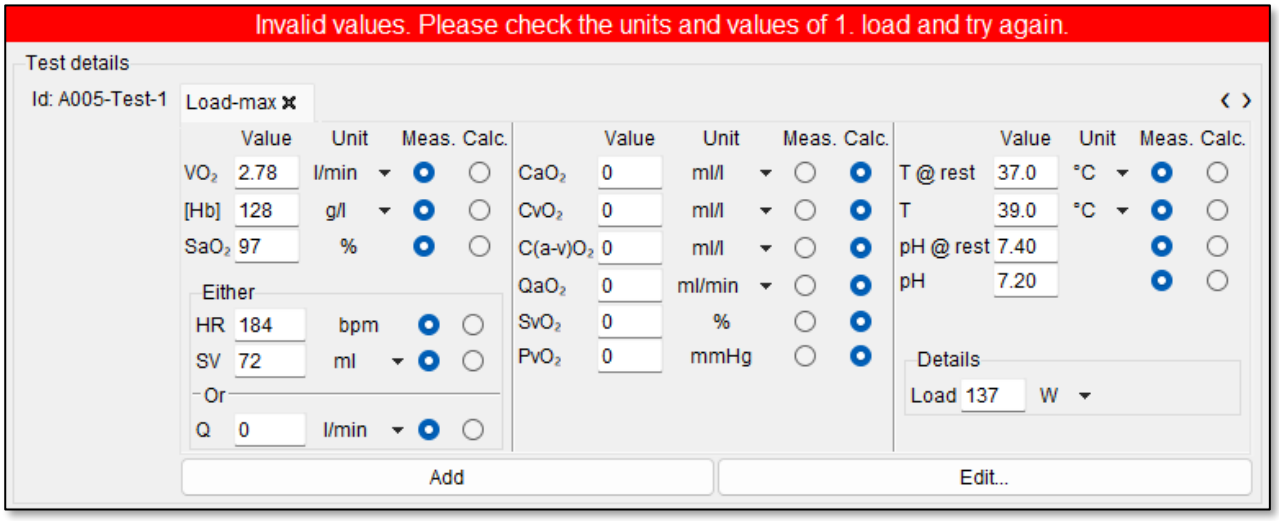


Figure 56

To fix the first situation do the following:

1. Open default settings from the "**Settings**" menu in the main menu bar (Figure 57).

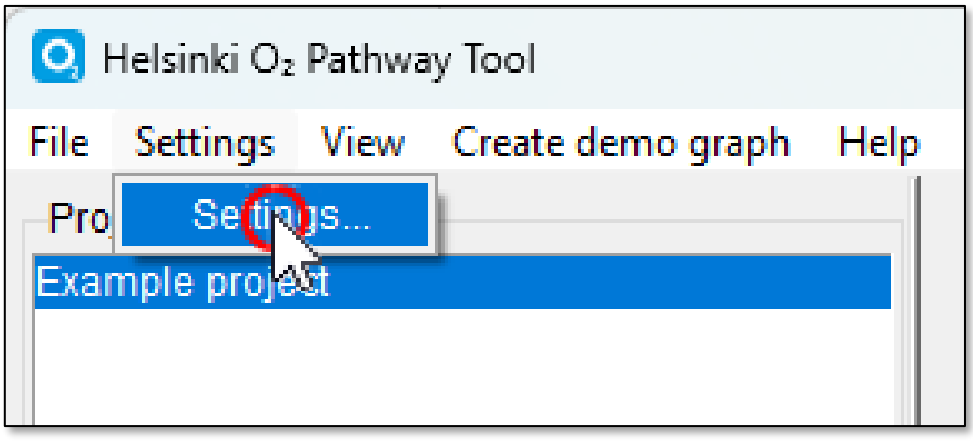


Figure 57

2. Change the incorrect unit by clicking the corresponding parameter's drop-down menu button (Figure 58).
3. Save changes by clicking the "**Save**" button (Figure 58).
4. The test details module is updated with the new default settings and the model can be created.

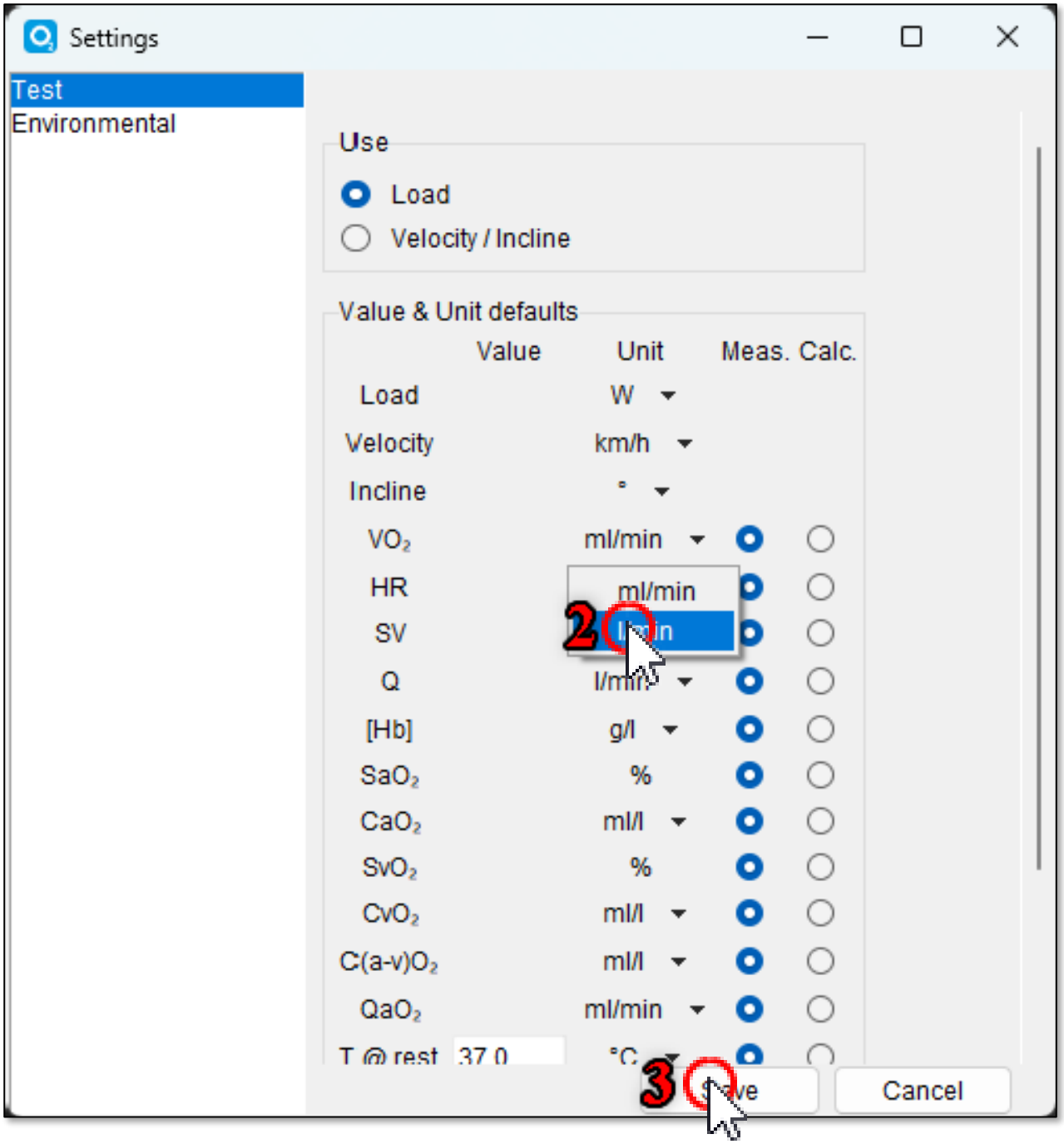


Figure 58