Analysis and display of data from pediatric CPET with SCILAB

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1. Background

Cardiopulmonary Exercise test (CPET) is a gold standard method for the assessment of cardiopulmonary fitness. Cardiopulmonary fitness is an important criterion in medical care. Indeed, low levels of cardiorespiratory fitness are associated with high risk of cardiovascular disease, and all-cause mortality, as well as mortality rates. (1) Obviously, exercise test is often used in cardiologic clinicals. CPET consist of maximal or symptom-limited test, with continuous recording of an electrocardiogram, gas exchange, blood pressure and other physiologic and perceptual responses. Then, variables are collected and utilized for interpretation, and provide the medical report to patients (2). Thus, this step is particularly important and is time consuming. Furthermore, interpretation and collection of date depends directly of the software used. In our laboratory, we always use **COSMED software.** If you are using another software, scripts will not run correctly. Indeed, COSMED software generates csv.file with specific rows and columns, so the script is only running on this type of file.

2. Problematic

As we saw before, interpretation of physiological variables, generated by cosmed software takes times, and could introduced some errors.

Well-functioning of clinical service depends of time used for patient medical check-up. If we can minimize waiting time for patients in the waiting room, it is a good argument to promote process automation. In addition, cardiologist reports, by themselves, values in pre-print medical report. So, this step could introduce a lot of errors. Therefore, it could be interesting to paste values automatically in standardized pre-print medical report (.txt). Then, cardiologists must check if the scripts have run correctly, and report some adverse event / or missing values that was not written in COSMED **xls.file**. Medical report could be printed and given to the patient right after ending exercise test.

Updating data base is a major issue as well, that process automation can resolve easily. From researcher point of view, updating date base could be interesting to analyze cardiopulmonary variables from large cohorts. In the end, large cohort analyses could be used for publication.

3. Aims

- To help health professional to report CPET Data in preprint medical report. To improve the reliability of report data by programming language.
- To save data from all patient in protected and confidential database.

4. Pre-requisite

4.1. CPET Data extraction

Make sure that your CPET software is COSMED.

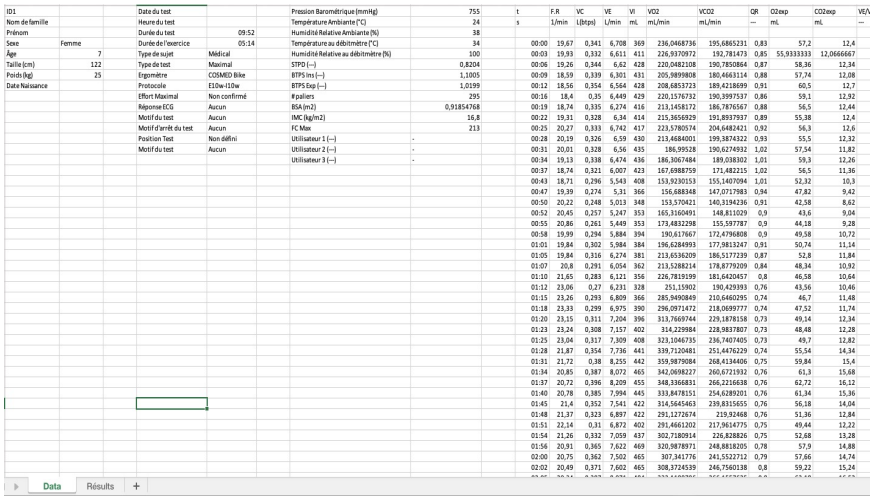
4.2. Data extracted (.xlsx) look like this (as below):

- Sheet 1-Data: Detailed results, recording of variable all along CPET Time

Spirométrie										
Paramètre	**um**	**Pré**	**% Préd.**	**Post Ex**	**% Change**	**Normal**	**Niveau**			
CVF	L	1,58	104	-	-					
VEMS	L	1,36	99	-	-	>1,22				
VMV	L/min	47,6	-							
Protocole										
Paramètre	**um**	**Mesure**	**Repos**	**Échauffement**	**SV1**	**SV2**	**Max**	**Préd.**	**% Préd.**	**Normal**
t	s				03:57		06:54			
Power	Watt			10	40		70			---
Revolution	RPM			62	69		45			
Métabolique										
Paramètre	**um**	**Mesure**	**Repos**	**Échauffement**	**SV1**	**SV2**	**Max**	**Préd.**	**% Préd.**	**Normal**
VO2	mL/min		203	256	638		1015	1000	102	>840
VO2/kg	mL/min/Kg		8,1	10,2	25,5		40,6	40	102	>33,6
METS	---		2,3	2,9	7,3		11,6	-	-	---
QR	---		0,93	0,81	1,01		1,08	-	-	---
Ventilatoire										
Paramètre	**um**	**Mesure**	**Repos**	**Échauffement**	**SV1**	**SV2**	**Max**	**Préd.**	**% Préd.**	**Normal**
Pente VE/VCO2	---	35,5						-	-	---
VE/VCO2 interc.	L/min	-1,7								
OUES	ml/min/l/min	1016								---
VE	L/min		6,4	6,6	21,2		35,8			
RR	%				55,4		24,8	-	-	---
VC	L(btps)		0,333	0,307	0,749		0,692			
F.R	1/min		19,2	21,4	28,3		51,7			
Cardiovasculaire										
Paramètre	**um**	**Mesure**	**Repos**	**Échauffement**	**SV1**	**SV2**	**Max**	**Préd.**	**% Préd.**	**Normal**
FC	bpm		69	82	111		151	213	71	>192
RFC	bpm	62						-	-	---
FCR_1_minute	bpm	54						-	-	---
Pente VO2/Puiss.	mL/min/Watt	13,79						-	-	---
VO2/FC	mL/beat		3	3,1	5,7		6,7	-	-	---
Échanges Gazeux										
Paramètre	**um**	**Mesure**	**Repos**	**Échauffement**	**SV1**	**SV2**	**Max**	**Préd.**	**% Préd.**	**Normal**
VO2@SV1	mL/min	638						400	160	>400
PetCO2	mmHg		36	36	35		33			
PetO2	mmHg		109	103	112		116			
VE/VO2	---				30,2		33,3			
VE/VCO2	---				29,7		30,8	-	-	---

Data | Résults | +

- Sheet 2- Results: Synthetic results with Time of measure and labels of CPET Variables



ID1		Date du test		Pression Barométrique (mmHg)	755	t	F.R	VC	VE	VI	VO2	VCO2	QR	O2exp	CO2exp	VE/\
Nom de famille		Heure du test		Température Ambiante (°C)	24	s	1/min	L(btps)	L/min	mL	mL/min	mL/min	---	mL	mL	---
Prénom		Durée du test	09:52	Humidité Relative Ambiante (%)	38											
Sexe	Femme	Durée de l'exercice	05:14	Température au débitmètre (°C)	34	00:00	19,67	0,341	6,708	369	236,0468736	195,6865231	0,83	57,2	12,4	
Âge	7	Type de sujet	Médical	Humidité Relative au débitmètre (%)	100	00:03	19,93	0,332	6,611	411	226,9370972	192,781473	0,85	55,9333333	12,0666667	
Taille (cm)	122	Type de test	Maximal	STPD (—)	0,8204	00:06	19,26	0,344	6,62	428	220,0482108	190,7850864	0,87	58,36	12,34	
Poids (kg)	25	Ergomètre	COSMED Bike	BTPS Ins (—)	1,1005	00:09	18,59	0,339	6,301	431	205,9899808	180,4663114	0,88	57,74	12,08	
Date Naissance		Protocole	E10e-I10w	BTPS Exp (—)	1,0199	00:12	18,56	0,354	6,564	428	208,6853723	189,4218699	0,91	60,5	12,7	
		Effort Maximal	Non confirmé	#paliers	295	00:16	18,4	0,35	6,449	429	220,1576732	190,3997537	0,86	59,1	12,92	
		Réponse ECG	Aucun	BSA (m2)	0,91854768	00:19	18,74	0,335	6,274	416	213,1458172	186,7876567	0,88	56,5	12,44	
		Motif du test	Aucun	IMC (kg/m2)	16,8	00:22	19,31	0,328	6,34	414	215,3656929	191,8937937	0,89	55,38	12,4	
		Motif d'arrêt du test	Aucun	FC Max	213	00:25	20,27	0,333	6,742	417	223,5780574	204,6482421	0,92	56,3	12,6	
		Position Test	Non défini	Utilisateur 1 (—)	.	00:28	20,19	0,326	6,59	430	213,4684001	199,3874322	0,93	55,5	12,32	
		Motif du test	Aucun	Utilisateur 2 (—)	.	00:31	20,01	0,328	6,56	435	186,99528	190,6274932	1,02	57,54	11,82	
				Utilisateur 3 (—)	.	00:34	19,13	0,338	6,474	436	186,3067484	189,038302	1,01	59,3	12,26	
						00:37	18,74	0,321	6,007	423	167,6988759	171,482215	1,02	56,5	11,36	
						00:43	18,71	0,296	5,543	408	153,9230153	155,1407094	1,01	52,32	10,3	
						00:47	19,39	0,274	5,31	366	156,688348	147,0717983	0,94	47,82	9,42	
						00:50	20,22	0,248	5,013	348	153,570421	140,3194236	0,91	42,58	8,62	
						00:52	20,45	0,257	5,247	353	165,3160491	148,811029	0,9	43,6	9,04	
						00:55	20,86	0,261	5,449	353	173,4832298	155,597787	0,9	44,18	9,28	
						00:58	19,99	0,294	5,884	394	190,617667	172,4796808	0,9	49,58	10,72	
						01:01	19,84	0,302	5,984	384	196,6284993	177,9813247	0,91	50,74	11,14	
						01:05	19,84	0,316	6,274	381	213,6536209	186,5177239	0,87	52,8	11,84	
						01:07	20,8	0,291	6,054	362	213,5288214	178,8779209	0,84	48,34	10,92	
						01:10	21,65	0,283	6,121	356	226,7819199	181,6420457	0,8	46,58	10,64	
						01:12	23,06	0,27	6,231	328	251,15902	190,429393	0,76	43,56	10,46	
						01:15	23,26	0,293	6,809	366	285,9490849	210,6460295	0,74	46,7	11,48	
						01:18	23,33	0,299	6,975	390	296,0971472	218,0699777	0,74	47,52	11,74	
						01:20	23,15	0,311	7,204	396	313,7669744	229,1878158	0,73	49,14	12,34	
						01:23	23,24	0,308	7,157	402	314,229984	228,9837807	0,73	48,48	12,28	
						01:25	23,04	0,317	7,309	408	323,1046735	236,7407405	0,73	49,7	12,82	
						01:28	21,87	0,354	7,736	441	339,7120481	251,4476229	0,74	55,54	14,34	
						01:31	21,72	0,38	8,255	442	359,9879084	268,4134406	0,75	59,84	15,4	
						01:34	20,85	0,387	8,072	465	342,0698227	260,6721932	0,76	61,3	15,68	
						01:37	20,72	0,396	8,209	455	348,3366831	266,2216638	0,76	62,72	16,12	
						01:40	20,78	0,385	7,994	445	333,8478151	254,6289201	0,76	61,34	15,36	
						01:45	21,4	0,352	7,541	422	314,5645463	239,8315655	0,76	56,18	14,04	
						01:48	21,37	0,323	6,897	422	291,1272674	219,92468	0,76	51,36	12,84	
						01:51	22,14	0,31	6,872	402	291,4661202	217,9614775	0,75	49,44	12,22	
						01:54	21,26	0,332	7,059	437	302,7180914	226,828826	0,75	52,68	13,28	
						01:56	20,91	0,365	7,622	469	320,9878971	248,8818205	0,78	57,9	14,88	
						02:00	20,75	0,362	7,502	465	307,341776	241,5522712	0,79	57,66	14,74	
						02:02	20,49	0,371	7,602	465	308,3724539	246,7560138	0,8	59,22	15,24	

Data | Résults | +

4.3. Save as XLS file

Then, open this .xlsx file, and save as: "filename.xls". Be careful with this step, the script runs **xls.file ONLY** and filename have to be short name, no special character, punctuation marks, or blanks.

5. Import data in Scilab

5.1. Installation of Scilab

You first need to install Scilab on: **https://www.scilab.org**

Code de champ modifié

5.2. ScilabDataAnalysisTemplate

We used ScilabDataAnalysisTemplate available on:

https://github.com/DenisMot/ScilabDataAnalysisTemplate#scilabdataanalysistemplate

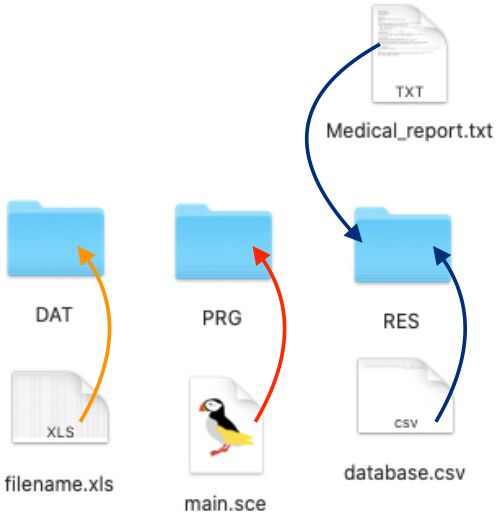
Code de champ modifié

This is a template for data analysis with scilab. You have to follow this organization structure.

- PRG providing a minimum set of ingredients for CPET analysis: that we explain later (see chapter XXX)
    - getValue.sci
    - PasteValue.sci
    - getInformation.sci
    - PasteInformation.sci
  - initTRT.sce (structure organization)

- *Do not modify the names and organisation of the directories*

  The DAT+PRG+RES structure is expected when initialising in InitTRT.sce



6. Script manipulation

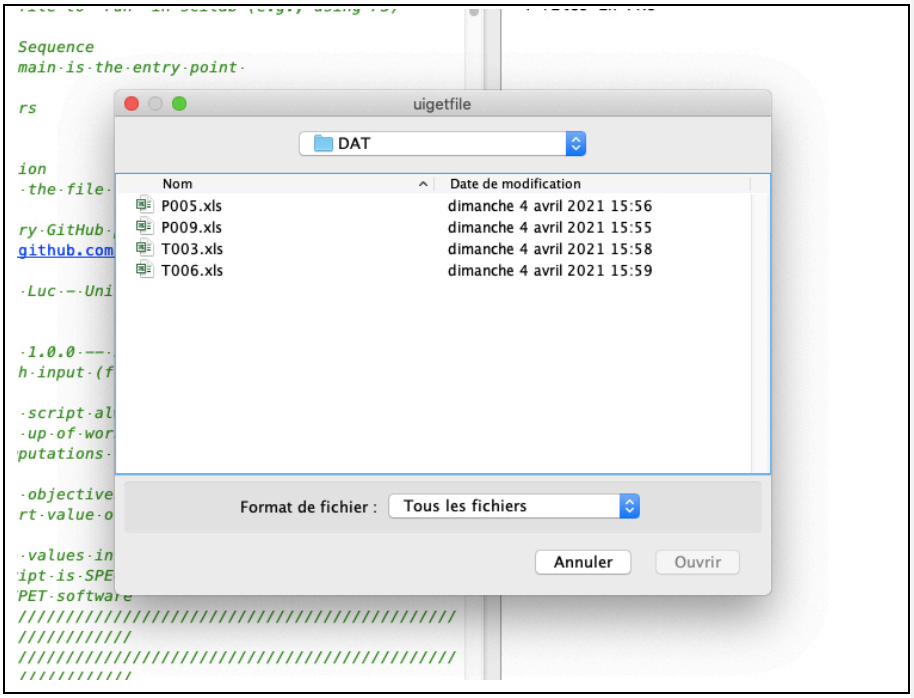
6.1. How to run the script?

On your computer:

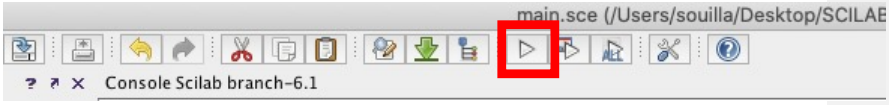
- Open main.sce
- Double click on main.sce might not work... depending on your OS.

  Opening files from SciNotes always works (File menu -> open).

- Dialog window will open with uigetfile name. Choose your file, then “Open”.



- Then, you can click on “execute”. See the picture below



6.2. How does function in PRG work?

We created four different functions placed in PRG file:

6.2.1. getValue.sci

This function read a value of interest in sheet 2 “Results”. We need to know the line and the column.

For the application of this function, you need to give three input argument:

1- *Measure*: What we want to read

2- *TimeOfMeasure:* Where/which moment do we want to read measure

3- *Valsheet*: Scilab matrix which contains "results" data (sheet 2) of CPET

4- *Example:*

```
RerMax= getValue(Val_res,"QR","Max");

In Val_res matrix, get value of Maximum Respiratory Exchange ratio
at maximum of the effort.
```

6.2.2. getInformation.sci

This function reads a value of interest in sheet 1 "Data". For the application of this function, you need to give two input arguments:

1- *Measure*: Information of interest, what we want to read

2- *Namefile*: Scilab matrix which contains "Data" (sheet 1) of CPET

3- *Example:*

```
DateOfBirth=getInformation("Date Naissance",Str_info);

In Str_info matrix, get value of "Date Naissance".
```

6.2.3. PasteValue.sci

This function pastes our value of interest (cf: getValue.sci) in DataBase file. We need to know the index line and column to paste value in correct cell. For the application of this function, you need to give three input argument:

1- *Measure*: What we want to paste

2- *TimeOfMeasure:* Where/which moment we want to paste

3- *Value*: The previous value that we got with getValue.sci

4- Namefile: Scilab matrix opened from database file (RES file)

5- *Example:*

```
DataBase=PasteValue(DataBase, RerMax ,"QR","Max") ;

In DataBase, paste RerMax (getValue.sci), with index of Respiratory
quotient at maximum.
```

6.2.4. PasteInformation.sci

This function pastes our information of interest (cf:getInformation.sci) in DataBase file. For the application of this function, you need to give three input arguments:

1- *Measure:* What we want to read in namefile
2- *Value*: Values that we got with getInformation.sci
3- *Namefile:* Scilab matrix opened from database file (RES file), and we paste information into it

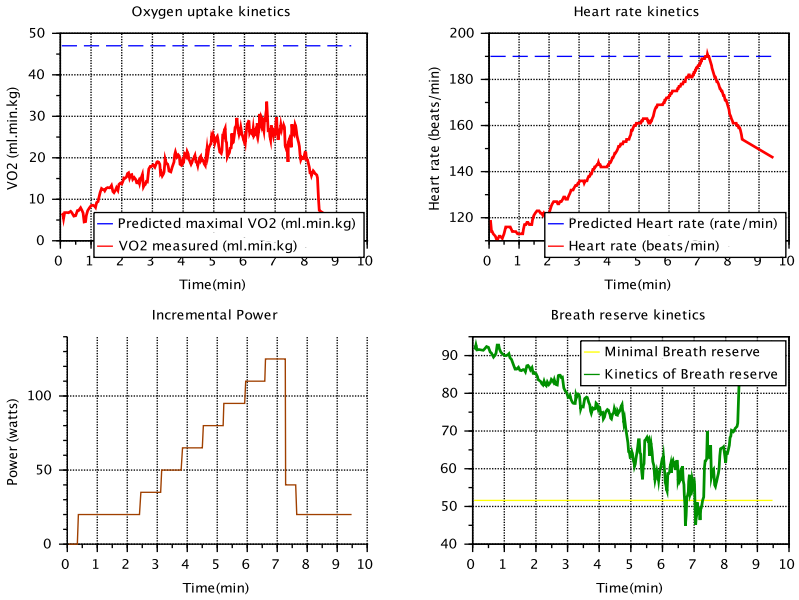
4- *Example*:

```
DataBase=PasteInformation(DataBase,DateOfBirth,« Date Naissance »);

In DataBase, paste DateOfBirth(getInformation.sci), with index of "Date
Naissance". Use this index to paste DateOfBirth value got by
getInformation.
```

6.2.5. Display graphic in Scilab Console

At the end of the script, I created a "BONUS plot", that will save in RES file as: "Graphics_Name.pdf". It could be help to judge about maximality of CPET. Even if COSMED software offers some graphics, you can, in the same time, run script on scilab and get graphics is displayed in the console. I have often used kinetics in pediatrics population, because maximality criterion is not evident as much as it could be in adult population.
In addition, graphics make interpretation easier for health professionals. In that sense, I make a representation of predicted values versus values measure on the same graph.
Finally, you can print this graphics (RES file) and keep in medical file of patient.
As an extra tip, make sure that you delete graphics and medical report in RES file, because when you will run a bunch of patient scripts, RES file could be full of graphics and medical report. So, cleaned up your RES file as soon as you get time.



6.3. Can we modify the script?

Every cardiology service has its own medical report. Obviously, you can change sentence in medical report. I wrote some example down:

6.3.1. Sentences in medical report

Our medical report pre-print cannot be correct for all cardiologist center. It has to fit to your data as much as possible.

```
Initial instructions :
Medical_report(27,1)=("Réserves ventilatoires entamées/non entamées à ")+string(BreathresMax)+" % ";

You can modify instructions:
Medical_report(29,1)=(" Réserves ventilatoires en fin d'effort est égale à  ")+string(BreathresMax)+" % ";
```

6.3.2. Variable's name

Variables name's is editable as much as you want BUT you have to change variable name in ALL script, even in function if it necessary. To do this, you can simply click on Edit> Search> Replace

6.3.3. Change Values pasted

In this script, I choose some variables interesting in my topic. You can easily pick another value by get value function, and paste by PasteValue function.

I give an example right here:

```
Initial instructions:
StrCpet=["Power","VO2","VO2/kg","QR","VE","RR","VC","F.R","FC","VO2/FC","P
Syst","P Diast","PetCO2","PetO2","VE/VO2","VE/VCO2"];
        CollectMax=getValue(Val_res,StrCpet,"Max");
        DataBase=PasteValue(DataBase,CollectMax,StrCpet,"Max");
```

```
If you want, you can pasted less value, and during Ventilatory anaerobic
threshold (VAT):
        StrCpet=[VO2","VO2/kg","FC","VO2/FC"];
        CollectMax=getValue(Val_res,StrCpet,"SV1");
        DataBase=PasteValue(DataBase,CollectMax,StrCpet,"SV1");

This instruction pastes VO2, VO2/kg, FC, VO2/FC at Ventilatory Anaerobic
Threshold in DataBase file.
```

6.4. If Scilab console display error message

Make sure that your file has no empty cell or missing values. For example, if VO2 doesn't appear in your input file (.xls), Scilab console displays error message.

I gave some examples of modification, but you can do as you prefer. This script must fit to your problematic, so feel free to modify some instructions.

6.5. Before saving and printing medical report

After running script, you can edit, modify, print txt file. You have to click on RES file, and find .txt file with matching name. Then, make sure that you have respected following rules:

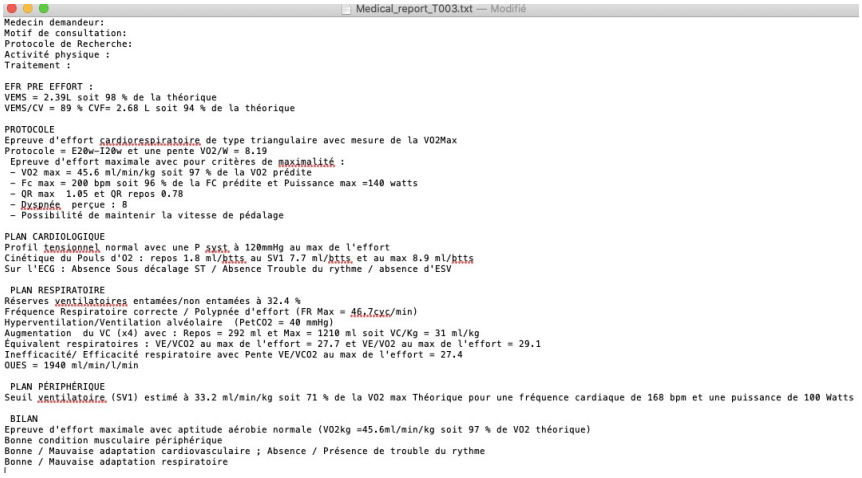
1- Complete header of medical report (lines 1 to lines 5). Be careful to keep file anonymous.

2- Write in “Plan cardiologique” if there some adverse events on ECG. You can write them down on line “: Sur l’ECG “. **Script doesn’t interpretate EKG**, and adverse events have to be reported by cardiologist.

3- Write in “Bilan”, the interpretation of CPET variables. **Script doesn’t interpretate CPET variables**. Script only interpretates VO2 value, if VO2peak >80 % predicted value, it’s written “Maximal CPET”, following by VO2 peak value. If it not the case, it’s written” Not maximal CPET”, so you have to be moderate in your interpretation.

4- Check all values, and correct some incoherent values with input file drop in DAT file.

5- Now, you can print or save your medical report



7. Data base output

After running script, you can check if values have been printed in Output Database file (RES file). If it not the case, try to run at another time. Data base will store new lines for each patient. Over time, lines are accumulating in table, it is practical way to make a database of all of your patient.

As an extra tip, make sure that you haven't simultaneously open database output file and run script in Scilab. In that case, database output could not be updated by patient that you have just add by running script.

8. Perspective

- Makes interpretation more effective. As we mentioned before, pediatric CPET have a lot of inter-variability. It is complicated to make automatic interpretation of maximality (ex: Respiratory variables interpretation). It could be interesting to explore a lot of data in pediatrics in order to improve our script and improve our interpretation process.

Commenté [JC1]: Les « contractions » sont plutôt à l'oral.

- If you're working with adults, you can modify some instructions to give more automatization process in your script. For example, maximal criteria of CPET in adults is the same for all of them, so you can modify script and making it more effective.

- This script didn't interpret any values of EKG. A domain- expert professional have to check, and register if a serious adverse event takes place. Over time, we could improve our script, and using row data (sheet 1) to detect some serious adverse events.

- Application of this script is limited on COSMED Software. One of these perspectives is his application in other major CPET software.

9. Conclusion

This script was made for helping health professionals, cardiologists using CPET Cosmed software. To some extent, process automatization makes life easier, they do not have to write down themselves medical report anymore. Scripts do it with some sentences pre-print, and could be modified for fitting as much as possible for your population. Second, professionals CPET user's save a lot time, and they just interpretate CPET values print on medical report.
On top of that, this Scilab script stores values of all patient who have done CPET in Output database file. You can analyze different CPET patient in the same time, but keep in mind data protection principles.
On the whole, this script is useful for sure, but it cannot replace human being verification, particularly during adverse event occurrence and/or interpretation or missing values during CPET. Actually, it's not our objectives by create this script.

Watch TUTORIAL VIDEO : ***https://youtu.be/AKPK5kO6MOo***

10. Bibliography

1. Ross R, Blair SN, Arena R, Church TS, Després J-P, Franklin BA, et al. Importance of Assessing Cardiorespiratory Fitness in Clinical Practice: A Case for Fitness as a Clinical Vital Sign: A Scientific Statement From the American Heart Association. Circulation. 13 déc 2016;134(24):e653-99.

2. Ross RM. ATS/ACCP statement on cardiopulmonary exercise testing. Am J Respir Crit Care Med. 15 mai 2003;167(10):1451; author reply 1451.

3. Download Scilab software: https://www.scilab.org/download/6.1.0

4. ScilabDataAnalysisTemplate created by Denis Mottet (Université de Montpellier) available on : https://github.com/DenisMot/ScilabDataAnalysisTemplate

Code de champ modifié