

Supplemental Material

Title: A comparison of alternative selection methods for reporting spirometric parameters in healthy adults

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Sample R code for the ATS/ERS selection method

The ensuing code is provided for the ATS/ERS selection method as it was the most complex to code. Code for other selection criteria followed a modified version:

```
# To begin with the selection of maneuvers for intra-session comparison, first any patient visits with less than two trials are filtered out
```

```
criteria1.step1 <- accepted.data %>%  
  group_by(patientID,visit) %>%  
  filter(n())>2)
```

```
# Variables are created to identify repeatability criteria: the cumulative max for FVC and FEV1, cumulative second max for FVC and FEV1, sum of FVC and FEV1 (to be used for selecting other parameters of interest)
```

```
criteria1.step2 <- criteria1.step1 %>%  
  mutate(nxtFVC = map_dbl(.x = seq_along(FVC), ~ ifelse(.x==1,NA,FVC[order(-FVC[1:.x])[2]])),  
    nxtFEV1 = map_dbl(.x = seq_along(FEV1), ~ ifelse(.x==1,NA,FEV1[order(-FEV1[1:.x])[2]])),  
    maxFVC = cummax(FVC),  
    maxFEV1 = cummax(FEV1),  
    sumFVC_FEV1 = (FVC + FEV1))
```

```
# We define two variables that we will use in the next step to help us identify if each maneuver meets repeatability (the difference between the cumulative max and cumulative second max for FEV1 and FVC); we also define a variable for the ratio of max FEV1/FVC
```

```
criteria1.step2$rep_FEV1 <- (criteria1.step2$maxFEV1- criteria1.step2$nxtFEV1)  
criteria1.step2$rep_FVC <- (criteria1.step2$maxFVC- criteria1.step2$nxtFVC)  
criteria1.step2$ratio <- (criteria1.step2$maxFEV1/ criteria1.step2$maxFVC)
```

```
# First, any subjects not able to achieve repeatability across their maneuvers are filtered out. Then, a repeatability indicator variable is created that sequenced along each row of maneuver data indicating "YES" if repeatability established (rep_FEV1 and rep_FVC less than or equal to 0.15), or "NO" if this condition not met. Then, for each subject and visit, all rows were selected starting at their first row up to and including the first repeatable maneuver after at least three maneuvers performed.
```

```
(criteria1.step3 <- criteria1.step2 %>%  
  filter(any(rep_FEV1<=0.15 & rep_FVC<=0.15 & trial>2)) %>%  
  mutate(repeatable = ifelse((rep_FEV1<=0.15 & rep_FVC<=0.15 & trial>2),"YES","NO")) %>%  
  slice(1: min(which(repeatable == "YES"))))
```

```
# Finally, FEV1, FVC and all other parameters were selected for inter-session comparisons from the set of repeatable maneuvers selected above for intra-session comparisons
```

```
criteria1.FEV1 <- criteria1.step3 %>%  
  slice_max(FEV1,n=1,with_ties=FALSE)
```

```
criteria1.FVC <- criteria1.step3 %>%  
  slice_max(FVC,n=1,with_ties=FALSE)
```

```
criteria1.other <- criteria1.step3 %>%  
  slice_max(sumFVC_FEV1,n=1,with_ties=FALSE)
```

Secondary analyses

Table S1. Intra-session descriptive statistics: FVC and FEV₁

Criteria	Variable	Visit 1			Visit 2		
		N	Median (IQR)	Mean ± SD	N	Median (IQR)	Mean ± SD
Dataset: all subjects regardless of complete data across visits or selection methods							
ATS/ERS standard & ATS/ERS mean	FEV ₁	317	3.33 (2.82, 3.93)	3.39 (0.80)	354	3.11 (2.60, 3.80)	3.24 (0.79)
	FVC	317	4.02 (3.43, 4.78)	4.11 (0.93)	354	3.72 (3.15, 4.54)	3.92 (0.96)
Mean of all, Mean of 3 largest	FEV ₁	544	3.29 (2.79, 3.89)	3.36 (0.77)	619	3.13 (2.62, 3.79)	3.22 (0.77)
	FVC	544	4.00 (3.37, 4.70)	4.07 (0.90)	619	3.72 (3.16, 4.52)	3.90 (0.93)
Peak Effort	FEV ₁	543	3.31 (2.76, 3.91)	3.37 (0.80)	612	3.14 (2.63, 3.84)	3.23 (0.77)
	FVC	543	4.00 (3.33, 4.70)	4.07 (0.92)	612	3.74 (3.16, 4.53)	3.91 (0.92)
Dataset: subjects in both visits but not in all selection methods (due to repeatability)							
ATS/ERS standard & ATS/ERS mean	FEV ₁	283	3.24 (2.75, 3.80)	3.32 (0.79)	289	3.23 (2.73, 3.85)	3.30 (0.78)
	FVC	283	3.90 (3.32, 4.67)	4.04 (0.94)	289	3.82 (3.30, 4.66)	4.02 (0.95)
Mean of all, Mean of 3 largest	FEV ₁	499	3.24 (2.75, 3.80)	3.31 (0.77)	524	3.20 (2.74, 3.85)	3.28 (0.74)
	FVC	499	3.87 (3.30, 4.59)	4.02 (0.91)	524	3.80 (3.31, 4.64)	4.00 (0.91)
Peak Effort	FEV ₁	481	3.28 (2.76, 3.86)	3.36 (0.80)	503	3.20 (2.73, 3.87)	3.30 (0.78)
	FVC	481	4.00 (3.32, 4.65)	4.05 (0.91)	503	3.85 (3.27, 4.59)	3.99 (0.90)

Table S2. Intra-session descriptive statistics: PEF and FEF₂₅₋₇₅

Criteria	Variable	Visit 1			Visit 2		
		N	Median (IQR)	Mean ± SD	N	Median (IQR)	Mean ± SD
Dataset: all subjects regardless of complete data across visits or selection methods							
ATS/ERS standard & ATS/ERS mean	PEF	317	6.88 (5.74, 8.03)	7.02 (2.06)	354	7.00 (5.84, 8.31)	7.24 (2.15)
	FEF ₂₅₋₇₅	317	3.44 (2.72, 4.39)	3.60 (1.11)	354	3.35 (2.67, 4.19)	3.46 (1.06)
Mean of all, Mean of 3 largest	PEF	544	6.74 (5.69, 7.90)	6.97 (2.03)	619	6.96 (5.84, 8.24)	7.18 (2.08)
	FEF ₂₅₋₇₅	544	3.43 (2.77, 4.31)	3.56 (1.06)	619	3.36 (2.66, 4.14)	3.44 (1.04)
Peak Effort	PEF	543	6.81 (5.77, 7.94)	7.05 (2.07)	612	7.02 (5.87, 8.25)	7.21 (2.10)
	FEF ₂₅₋₇₅	543	3.48 (2.76, 4.37)	3.60 (1.11)	612	3.40 (2.65, 4.22)	3.46 (1.06)
Dataset: subjects in both visits but not in all selection methods (due to repeatability)							
ATS/ERS standard & ATS/ERS mean	PEF	283	6.68 (5.56, 7.97)	6.92 (2.12)	289	7.09 (6.00, 8.50)	7.38 (2.10)
	FEF ₂₅₋₇₅	283	3.35 (2.71, 4.21)	3.50 (1.05)	289	3.38 (2.67, 4.22)	3.45 (1.01)
Mean of all, Mean of 3 largest	PEF	499	6.67 (5.52, 7.88)	6.91 (2.07)	524	7.08 (6.08, 8.29)	7.33 (2.03)
	FEF ₂₅₋₇₅	499	3.36 (2.76, 4.22)	3.50 (1.01)	524	3.39 (2.69, 4.18)	3.45 (0.99)
Peak Effort	PEF	481	6.73 (5.79, 7.92)	7.06 (2.11)	503	7.11 (6.23, 8.37)	7.45 (2.08)
	FEF ₂₅₋₇₅	481	3.50 (, 2.76, 4.37)	3.59 (1.09)	503	3.46 (2.66, 4.25)	3.51 (1.08)
Dataset: subjects in both visits and in all selection methods (primary data set)							
ATS/ERS standard & ATS/ERS mean	PEF	246	6.74 (5.78, 7.98)	7.02 (2.10)	251	7.11 (6.23, 8.65)	7.52 (2.11)
	FEF ₂₅₋₇₅	246	3.48 (2.73, 4.29)	3.58 (1.07)	251	3.46 (2.71, 4.28)	3.52 (1.02)
Mean of all, Mean of 3 largest	PEF	440	6.70 (5.77, 7.88)	7.01 (2.07)	463	7.10 (6.26, 8.35)	7.43 (2.05)
	FEF ₂₅₋₇₅	440	3.49 (2.78, 4.32)	3.57 (1.04)	463	3.45 (2.68, 4.25)	3.50 (1.02)
Peak Effort	PEF	440	6.70 (5.77, 7.88)	7.01 (2.07)	463	7.10 (6.26, 8.35)	7.43 (2.05)
	FEF ₂₅₋₇₅	440	3.49 (2.78, 4.32)	3.57 (1.04)	463	3.45 (2.68, 4.25)	3.50 (1.02)

Table S3. Intra-session variability by selection method

Criteria	Variable	Overall Mean	Visit 1					Visit 2				
			N	SD	SRD	SRD%	CV%	N	SD	SRD	SRD%	CV%
Dataset: all subjects regardless of complete data across visits or selection methods												
ATS/ERS standard and mean	FEV ₁	3.31	317 maneuvers, 99 subjects	0.12	0.33	10.00	3.61	354 maneuvers, 110 subjects	0.10	0.28	8.60	3.11
	FVC	4.01	317 maneuvers, 99 subjects	0.11	0.30	7.47	2.70	354 maneuvers, 110 subjects	0.09	0.25	6.12	2.21
Mean of all, mean of 3 largest	FEV ₁	3.28	544 maneuvers, 99 subjects	0.11	0.32	9.68	3.50	619 maneuvers, 110 subjects	0.11	0.29	8.95	3.23
	FVC	3.98	544 maneuvers, 99 subjects	0.11	0.29	7.35	2.65	619 maneuvers, 110 subjects	0.10	0.27	6.84	2.47
Peak Effort	FEV ₁	3.30	543 maneuvers, 100 subjects	0.12	0.32	9.79	3.53	612 maneuvers, 109 subjects	0.11	0.30	8.97	3.24
	FVC	3.98	543 maneuvers, 100 subjects	0.11	0.29	7.40	2.67	612 maneuvers, 109 subjects	0.10	0.28	6.95	2.51
Dataset: subjects in both visits but not in all selection methods (due to repeatability)												
ATS/ERS standard and mean	FEV ₁	3.31	283 maneuvers, 90 subjects	0.12	0.33	10.08	3.64	289 maneuvers, 90 subjects	0.10	0.28	8.48	3.06
	FVC	4.03	283 maneuvers, 90 subjects	0.11	0.30	7.42	2.68	289 maneuvers, 90 subjects	0.09	0.26	6.34	2.29
Mean of all, mean of 3 largest	FEV ₁	3.30	499 maneuvers, 90 subjects	0.12	0.32	9.70	3.50	524 maneuvers, 90 subjects	0.10	0.28	8.55	3.09
	FVC	4.01	499 maneuvers, 90 subjects	0.11	0.29	7.30	2.63	524 maneuvers, 90 subjects	0.10	0.28	7.03	2.54
Peak Effort	FEV ₁	3.33	481 maneuvers, 87 subjects	0.12	0.33	9.80	3.54	503 maneuvers, 87 subjects	0.11	0.29	8.75	3.16
	FVC	4.02	481 maneuvers, 87 subjects	0.11	0.30	7.48	2.70	503 maneuvers, 87 subjects	0.10	0.29	7.16	2.59

SD = measurement error taken as root mean square error from fitted linear mixed effects model

Repeatability or smallest real difference (SRD) = $SD \times 2.77$

SRD% = $SRD \times 100 / \text{mean across both visits for outcome measure}$

CV% = $(SD / \text{mean}) \times 100$ across both visits for outcome measure

Table S4. Inter-session descriptive statistics

Criteria	Variable	Visit 1			Visit 2		
		N	Median (IQR)	Mean $\pm$ SD	N	Median (IQR)	Mean $\pm$ SD
Dataset: subjects in both visits but not in all selection methods (due to repeatability)							
ATS/ERS standard	FEV ₁	90	3.28 (2.82, 3.87)	3.38 (0.75)	90	3.29 (2.79, 3.87)	3.36 (0.76)
	FVC	90	3.99 (3.40, 4.76)	4.09 (0.92)	90	3.86 (3.37, 4.57)	4.07 (0.94)
ATS/ERS mean	FEV ₁	90	3.22 (2.74, 3.75)	3.30 (0.75)	90	3.18 (2.71, 3.81)	3.28 (0.75)
	FVC	90	3.89 (3.33, 4.66)	4.01 (0.91)	90	3.77 (3.30, 4.54)	3.99 (0.93)
Mean of all	FEV ₁	90	3.22 (2.73, 3.78)	3.30 (0.75)	90	3.18 (2.73, 3.82)	3.28 (0.75)
	FVC	90	3.88 (3.33, 4.64)	4.02 (0.91)	90	3.81 (3.32, 4.54)	3.99 (0.92)
Mean of 3 largest	FEV ₁	90	3.28 (2.80, 3.83)	3.36 (0.76)	90	3.25 (2.76, 3.91)	3.34 (0.76)
	FVC	90	3.89 (3.36, 4.71)	4.07 (0.93)	90	3.90 (3.38, 4.64)	4.06 (0.93)
Peak effort	FEV ₁	87	3.33 (2.78, 3.83)	3.38 (0.80)	87	3.30 (2.78, 3.90)	3.36 (0.76)
	FVC	87	4.01 (3.35, 4.61)	4.07 (0.93)	87	4.00 (3.35, 4.65)	4.07 (0.92)

Table S5. Inter-session descriptive statistics: PEF and FEF₂₅₋₇₅

Criteria	Variable	Visit 1			Visit 2		
		N	Median (IQR)	Mean ± SD	N	Median (IQR)	Mean ± SD
Dataset: subjects in both visits but not in all selection methods (due to repeatability)							
ATS/ERS standard	PEF	90	6.84 (5.70, 8.17)	7.09 (2.02)	90	7.40 (6.18, 8.47)	7.53 (2.10)
	FEF ₂₅₋₇₅	90	3.41 (2.77, 4.32)	3.57 (0.99)	90	3.43 (2.86, 4.31)	3.56 (1.00)
ATS/ERS mean	PEF	90	6.56 (5.69, 7.95)	6.91 (2.04)	90	7.07 (5.90, 8.31)	7.33 (2.06)
	FEF ₂₅₋₇₅	90	3.35 (2.73, 4.22)	3.48 (1.00)	90	3.31 (2.69, 4.24)	3.44 (0.97)
Mean of all	PEF	90	6.66 (5.80, 7.80)	6.92 (2.02)	90	7.01 (6.10, 8.18)	7.31 (2.06)
	FEF ₂₅₋₇₅	90	3.35 (2.74, 4.24)	3.46 (1.00)	90	3.35 (2.66, 4.20)	3.43 (0.97)
Mean of 3 largest	PEF	90	6.65 (5.69, 7.97)	7.02 (2.02)	90	7.21 (6.12, 8.46)	7.42 (2.09)
	FEF ₂₅₋₇₅	90	3.42 (2.76, 4.27)	3.53 (0.98)	90	3.40 (2.78, 4.24)	3.51 (0.98)
Peak effort	PEF	87	7.63 (6.50, 8.56)	7.73 (2.11)	87	7.80 (6.70, 8.97)	8.10 (2.14)
	FEF ₂₅₋₇₅	87	3.65 (2.71, 4.46)	3.60 (1.08)	87	3.45 (2.64, 4.22)	3.54 (1.03)
Dataset: subjects in both visits and in all selection methods (primary data set)							
ATS/ERS standard	PEF	78	6.86 (5.95, 7.98)	7.17 (2.01)	78	7.46 (6.30, 8.61)	7.66 (2.12)
	FEF ₂₅₋₇₅	78	3.52 (2.77, 4.39)	3.65 (1.01)	78	3.53 (2.89, 4.37)	3.64 (1.00)
ATS/ERS mean	PEF	78	6.60 (5.84, 7.96)	7.00 (2.04)	78	7.21 (6.18, 8.57)	7.49 (2.07)
	FEF ₂₅₋₇₅	78	3.50 (2.75, 4.27)	3.55 (1.02)	78	3.50 (2.73, 4.28)	3.52 (0.99)
Mean of all	PEF	78	6.79 (5.93, 7.93)	7.05 (2.01)	78	7.12 (6.31, 8.48)	7.47 (2.06)
	FEF ₂₅₋₇₅	78	3.54 (2.76, 4.26)	3.54 (1.02)	78	3.49 (2.67, 4.26)	3.51 (0.98)
Mean of 3 largest	PEF	78	6.75 (6.00, 8.02)	7.14 (2.01)	78	7.34 (6.34, 8.64)	7.60 (2.10)
	FEF ₂₅₋₇₅	78	3.60 (2.77, 4.36)	3.61 (1.00)	78	3.56 (2.82, 4.29)	3.59 (0.99)
Peak effort	PEF	78	7.35 (6.44, 8.56)	7.68 (2.09)	78	7.82 (6.67, 8.93)	8.05 (2.15)
	FEF ₂₅₋₇₅	78	3.63 (2.76, 4.47)	3.60 (1.02)	78	3.44 (2.63, 4.22)	3.52 (0.97)

Table S6. Inter-session variability by selection method

Criteria	Variable	N	Mixed effects ANOVA F value for visit	Mixed effects ANOVA p value for visit	Mean	SD	SRD	SRD%	CV%	ICC (95% CI)
Dataset: subjects in both visits but not in all selection methods (due to repeatability)										
ATS/ERS standard	FEV₁	180 (90 each visit)	1.00	0.32	3.37	0.08	0.22	6.52	2.36	0.98 (0.97, 0.99)
	FVC	180 (90 each visit)	2.23	0.14	4.08	0.06	0.18	4.38	1.58	0.99 (0.99, 0.99)
ATS/ERS mean	FEV₁	180 (90 each visit)	0.96	0.33	3.29	0.08	0.22	6.80	2.45	0.98 (0.97, 0.99)
	FVC	180 (90 each visit)	1.95	0.17	4.00	0.07	0.21	5.13	1.85	0.99 (0.98, 0.99)
Mean of all	FEV₁	180 (90 each visit)	1.16	0.28	3.29	0.07	0.19	5.91	2.14	0.98 (0.97, 0.99)
	FVC	180 (90 each visit)	3.12	0.08	4.01	0.06	0.17	4.36	1.57	0.99 (0.99, 0.99)
Mean of 3 largest	FEV₁	180 (90 each visit)	0.87	0.35	3.35	0.08	0.22	6.44	2.33	0.98 (0.97, 0.99)
	FVC	180 (90 each visit)	1.42	0.24	4.07	0.07	0.18	4.43	1.60	0.99 (0.99, 0.99)
Peak effort	FEV₁	174 (87 each visit)	1.08	0.30	3.37	0.10	0.27	8.14	2.94	0.97 (0.95, 0.98)
	FVC	174 (87 each visit)	0.03	0.86	4.07	0.09	0.24	5.89	2.13	0.98 (0.97, 0.99)

SD = measurement error taken as root mean square error from fitted linear mixed effects model

Repeatability or smallest real difference (SRD) = SDx2.77

SRD% = SRDx100/mean across both visits for outcome measure

CV% = (SD/ mean)x100 across both visits for outcome measure

ICC = intraclass correlation coefficient

95% CI = 95% confidence interval (lower, upper)

Table S7. Bland-Altman bias and limits of agreement for forced vital capacity (FVC) and forced expiratory volume in one second (FEV₁) by selection method across two visits. These values are plotted in the Bland Altman plots of the supplemental materials below (Figure S2).

Criteria	Variable	Bias (95% CI)	Lower Limit (95%CI)	Upper Limit (95% CI)
ATS/ERS Standard	FEV₁	0.01 (-0.02, 0.05)	-0.31 (-0.37, -0.25)	0.33 (0.27, 0.40)
	FVC	0.02 (-0.01, 0.05)	-0.24 (-0.29, -0.19)	0.28 (0.23, 0.33)
ATS/ERS Mean	FEV₁	0.01 (-0.03, 0.05)	-0.32 (-0.38, -0.25)	0.34 (0.27, 0.41)
	FVC	0.02 (-0.02, 0.05)	-0.28 (-0.35, -0.22)	0.32 (0.26, 0.38)
Mean of all	FEV₁	0.01 (-0.02, 0.05)	-0.27 (-0.32, -0.21)	0.30 (0.24, 0.35)
	FVC	0.02 (-0.01, 0.05)	-0.23 (-0.29, -0.18)	0.28 (0.23, 0.33)
Mean 3 largest	FEV₁	0.01 (-0.02, 0.05)	-0.30 (-0.36, -0.24)	0.32 (0.26, 0.38)
	FVC	0.01 (-0.02, 0.04)	-0.25 (-0.30, -0.19)	0.27 (0.22, 0.32)
Peak effort	FEV₁	0.02 (-0.02, 0.07)	-0.36 (-0.44, -0.29)	0.41 (0.33, 0.49)
	FVC	0.00 (-0.04, 0.04)	-0.34 (-0.41, -0.27)	0.33 (0.27, 0.40)

Figure S1. FEV₁ and FVC interaction plots for visit number vs. selection method (primary dataset, n = 78).

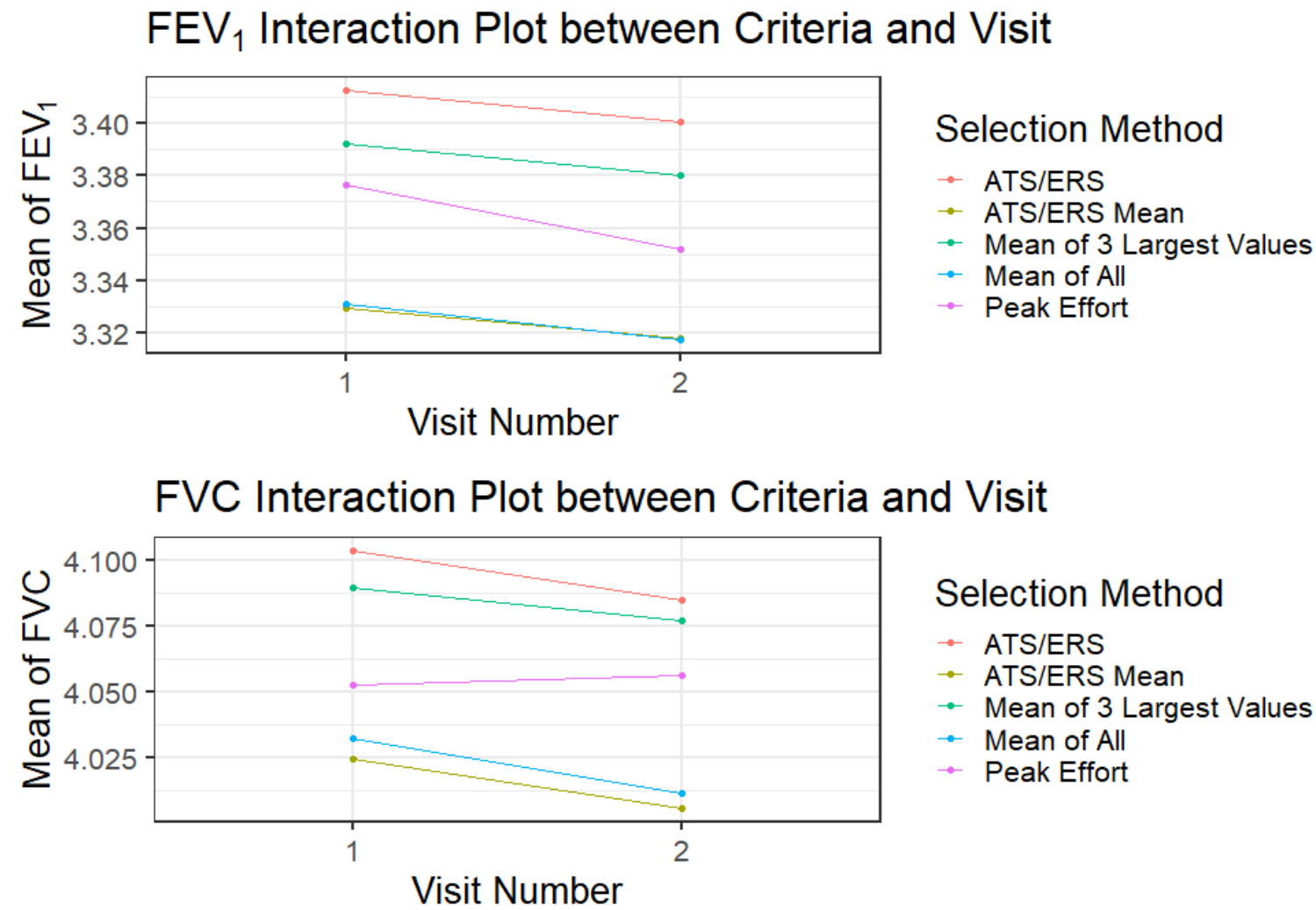


Figure S2. Bland Altman plots for FEV₁ and FVC by selection method (n = 78). Vertical and horizontal axes represent the difference (Visit 1 – Visit 2) and average values, respectively. The bias and 95% limits of agreement (dashed black horizontal lines) are plotted in red and blue dashed lines, respectively. The values used to construct these plots are reported in the Supplemental Material Table S7.

