
Supplementaries - SwinSleep: A Deep Learning Framework

Advancing Overnight Sleep Staging towards Clinical Practice

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Supplementary Tables

Table S1. Model hyperparameters

	Name	SwinSleep-E (Unit & Head)	SwinSleep-H (Head)
Task-specific hyperparameters	Sequence length	5 epochs (150 seconds)	1260 epochs (10.5 hours)
	Input length (L)	19200 (timepoint)	37800 (mixed feature)
	Input channel (C)	6 (3EEG + 2EOG + 1EMG)	48+60 (deep feature + meta feature)
	Patch size (P)	5	30
	Window size (W)	8	[1, 35, 45] epochs
Empirical hyperparameters	Embedding dim	48	48
	Layer depth	[2, 4, 2] & 4	[2, 4, 4]
	MLP ratio	2	2
	MSA head	4	4

Table S2. The original technical specifications and adopted channels in SwinSleep.

Cohort	3 EEG channels (alternate)	2 EOG channels (alternate)	1 EMG channel (alternate)	original scoring rule	explicit light events or in-bed time	Note
ABC	F4-M1 (F3-M2) C4-M1 (C3-M2) O2-M1 (O1-M2)	E1-M2 E2-M2 Unknown	Lchin-CChin	AASM*	✗	3 visits, adults with class II obesity and severe OSA
CCSHS	None C4-A1 (C3-A2) None	E1-A2 E2-A2	Cchin-Lchin	AASM*	✗	
CNC	F4-Fpz (F3-Fpz) C4-Fpz (C3-Fpz) O2-Fpz (O1-Fpz)	E1-Fpz E2-Fpz	Lchin-Rchin (Cchin-Fpz)	AASM	✗	
CFS	None C4-M1 (C3-M2) None	E1-M2 E2-M2	Cchin-Lchin	R&K, AASM*	✓	
DHC	F4-Fpz (F3-Fpz) C4-Fpz (C3-Fpz) O2-Fpz (O1-Fpz)	E1-Fpz E2-Fpz	Lchin-Rchin (Cchin-Fpz)	AASM	null	with daytime
DCSM	F4-M1 (F3-M2) C4-M1 (C3-M2) O2-M1 (O1-M2)	E1-M2 E2-M2	Chin EMG	AASM	null	With daytime
DOD	F4-M1 (F3-M2) C4-M1 (C3-M2) O2-M1 (O1-M2)	E1-M2 E2-M2	Chin EMG		✓	
HMC	F4-M1 C4-M1 (C3-M2) O2-M1	E1-M2 E2-M2	Chin		✓	
HPAP	F4-M1 (F3-M2) C4-M1 (C3-M2) O2-M1 (O1-M2)	E1-M2 E2-M2 (E2-M1)	Lchin-Cchin (Lchin-Rchin)	AASM	✗	AHI<15
IS-RC	None C4-A1 (C3-A2) O2-A1 (O1-A2)	LOC-A2 ROC-A1	EMG1-EMG2	AASM		
MASS13	F4-A2 (F3) C4-A2 (C3) O2-A2 (O1)	E1-A2 E2-A2	Chin1-Chin2		✗	
MESA	Fz-Cz C4-M1	E1-Fpz E2-Fpz	Lchin-Cchin	AASM	✗	

	Cz-Oz					
MROS	None C4-A1 (C3-A2) None	E1-A2 E2-A2	Lchin-Rchin	R&K, R&K (M), AASM*	✓	2 visits
NCHSDB	F4-M1 (F3-M2) C4-M1 (C3-M2) O2-M1 (O1-M2)	E1-M2 E2-M1	Chin1-Chin2 (Chin1-Chin3) (Chin3-Chin2)		✓	excluded subjects younger than 13 years old
PHY	F4-M1 (F3-M2) C4-M1 (C3-M2) O2-M1 (O1-M2)	E1-M2	Chin1-Chin2		✗	
SHHS	None C4-A1 (C3-A2) None	E1-Fpz E2-Fpz	Lchin-Rchin	R&K	✗	2 visits
SOF	None C4-A1 (C3-A2) None	E1-A2 E2-A2	Lchin-Rchin	R&K*	✓	
SSC	F4-Fpz (F3-Fpz) C4-Fpz (C3-Fpz) O2-Fpz (O1-Fpz)	E1-Fpz E2-Fpz	Lchin-Rchin (Cchin-Fpz)	AASM	✗	
WSC	None C3-M2 O1-M2	E1 E2	Chin	RNK	✓	

Table S3. Demographics of cohorts included in this study. Missing values are due to study design or unavailability. The demographic values represent summary statistics from the original study, which may be based on a greater number of observations due to our exclusion criteria.

purpose	Cohort	Subject Num	Record num	Subset / Visit	Length (minute)	Age (years)	Sex % (M/F)	BMI	AHI (events/hour)
Training & Evaluation	ABC	49	131		504.1±19.3	48.8 ± 9.8	57/43	38.9±2.9	50.1±26.9
	CCSHS	515	515		671.3±47.9	17.7±0.4	50/50	25.1±5.9	1.8±5.1
	CFS	722	722		593.1±53.6	41.4±19.4	45/55	32.3±9.4	11.4±16.1
	CNC	77	77		518.1±59.2	-	-	-	-
	HMC	154	154		452.7±73.9	53.9 ± 15.4	(56/44)	-	(14.6 ± 17.0)
	HPAP	245	190	full night	465.2±65.6	46.0±12.0	52/48	36.9±9.0	13.8±18.3
			55	split night	479.4±69.0	48.1±11.7	75/25	38.8±9.7	56.9±28.9
	MASS	115	115	SS1, SS3	482.5±39.5	52.2±17.8	-	-	-
	MESA	2034	2034		634.7±95.5	69.4±9.1	46/54		-
	MROS	2885	visit1		647.9±102.2	76.4±5.5	100/0	27.2±3.8	-
			1001	visit2	783.8±174.9	81.0±4.4	100/0	26.9±3.8	-
	NCHSDB	982	982	≥13 years	454.1±45.1	16.8±3.8	52/48	32.4±12.5	-
	PHY	993	993		449.1±39.3	(55 ± 14.3)	(67/33)	(33 ± 7.8)	(19 ± 14.6)
	SHHS	8288	5667	visit 1	506.0±37.5	63.1±11.2	48/52	28.2±5.1	18.0±16.1
			2621	visit 2	602.0±68.2	67.6±10.4	81/19	28.3±5.0	18.4±16.3
	SOF	449	449	visit 8	597.7±147.0	82.8±3.1	0/100	27.7±4.7	16.4±13.9
	SSC	768	768		471.4±53.4	-	-	-	-
	WSC	1116	2534	visit 1-5	459.3±46.3	62.3±8.5	54/46	31.7±7.3	11.8±15.0
Evaluation	DCSM	255	255		1135.2±75.6	-	-	-	-
	DHC	82	82		1051.6±197.4	-	-	-	-
	DOD	80	25	DOD-H	486.8±51.9	35.3 ± 7.5	24/76	23.8 ± 3.4	-
			55	DOD-O		45.6 ± 16.5	36/64	29.6 ± 6.4	-
	ISRC	69	69		602.1±62.7	(51.1 ± 4.2)	(0/100)	(32.9 ± 9.2)	(7.4 ± 12.3)

Supplementary Figures

Figure S1. Signal Processing Pipeline in SwinSleep Neural Network.

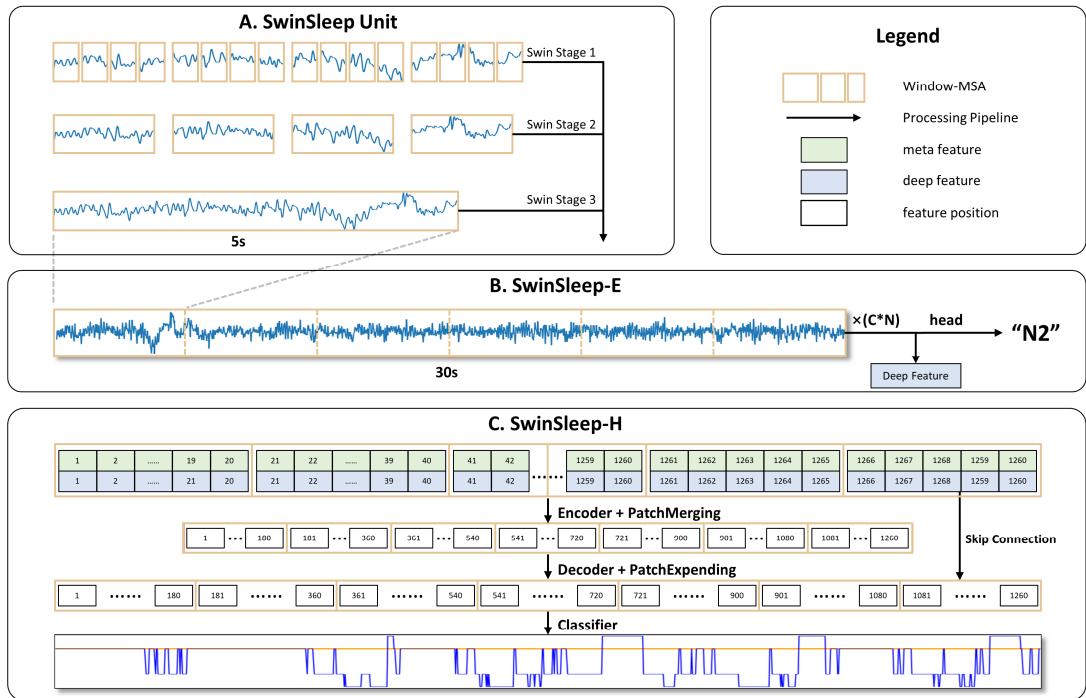


Figure S2. Confusion matrixes in mixed-cohort evaluation.

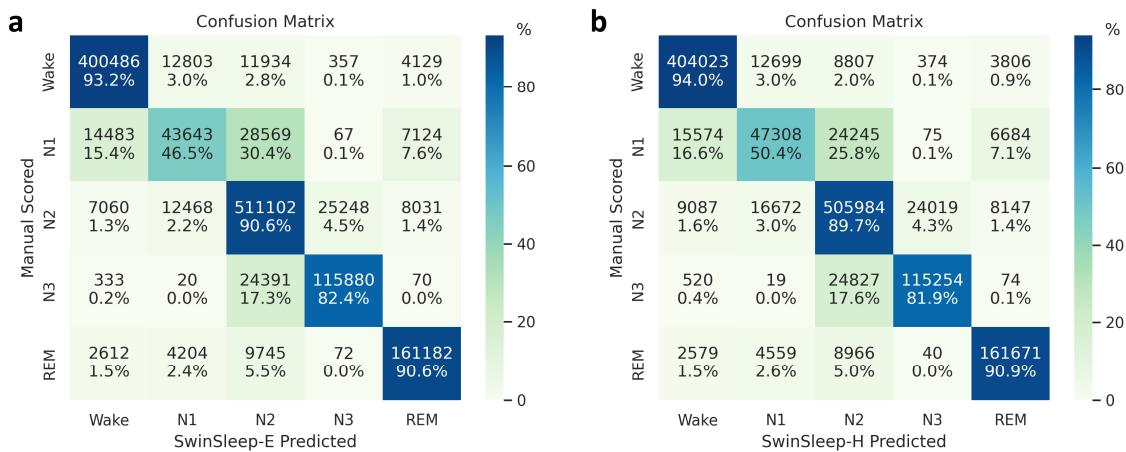


Figure S3. Comparison of prediction corrections. Examine the discrepancies in predicted stage assignments between SwinSleep-E and SwinSleep-H in the test set. a) presents the distribution of the stage combinations predicted by the two algorithms and whether they are correct. e.g., The orange bars in the row 1 and column 2 display the quantity (mean and 95% CI) of epochs correctly classified as Wake by SwinSleep-E, but then misclassified as N1 by SwinSleep-H in each PSG. b) presents the distribution of correctly and incorrectly classified epochs for each stage within individual PSGs. e.g., the Wake gray bar represents the quantity (mean and 95% CI) of epochs labeled as Wake in each PSG, which both SwinSleep-E and SwinSleep-H failed to classify accurately.

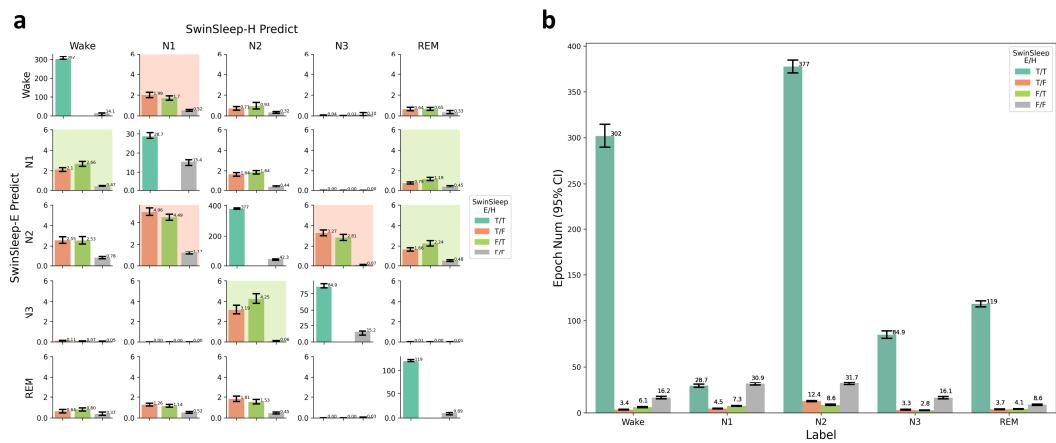


Figure S4. Overall stage transition probabilities on mixed-cohort test set, with sample sizes indicated next to each stage. Transition probabilities less than 1% are hidden.

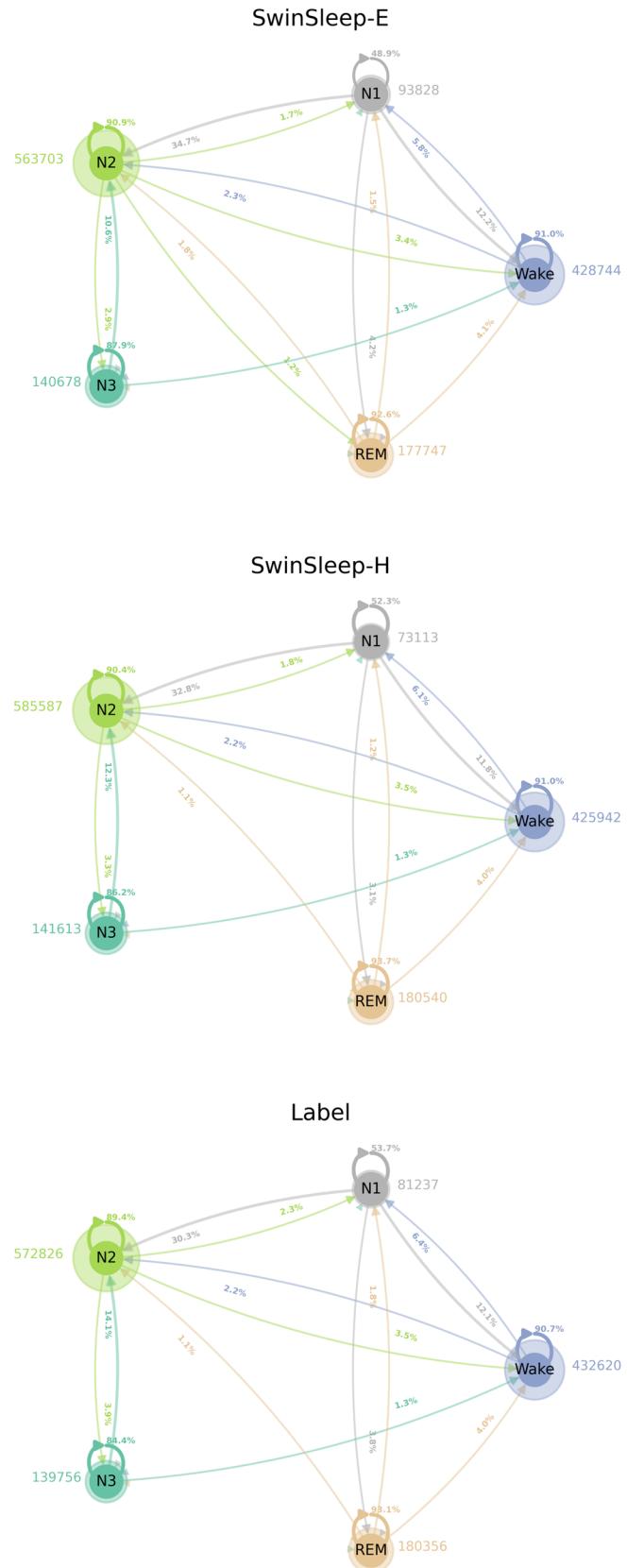


Figure S5. Accuracy distribution for manual and automated sleep scoring, tested in the DOD-H, DOD-O and IS-RC cohort.

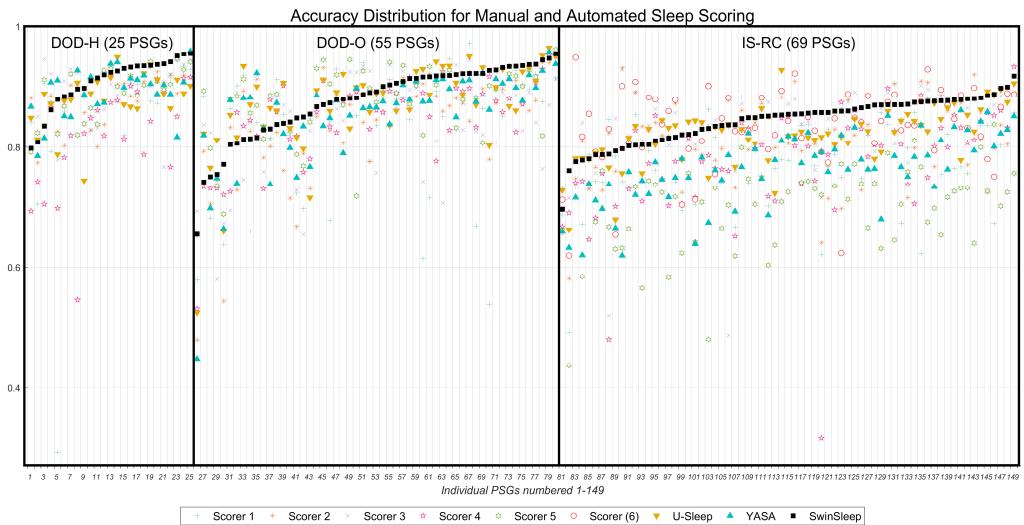


Figure S6. Cohen's Kappa distribution for manual and automated sleep scoring, tested in the DOD-H, DOD-O and IS-RC cohort.

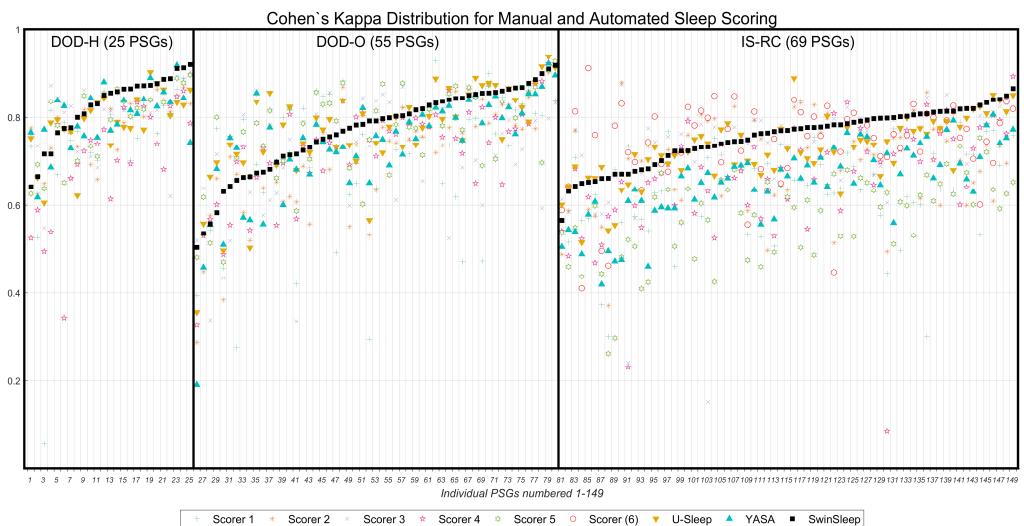


Figure S7. MF1 score distribution for manual and automated sleep scoring, tested in the DOD-H, DOD-O and IS-RC cohort.

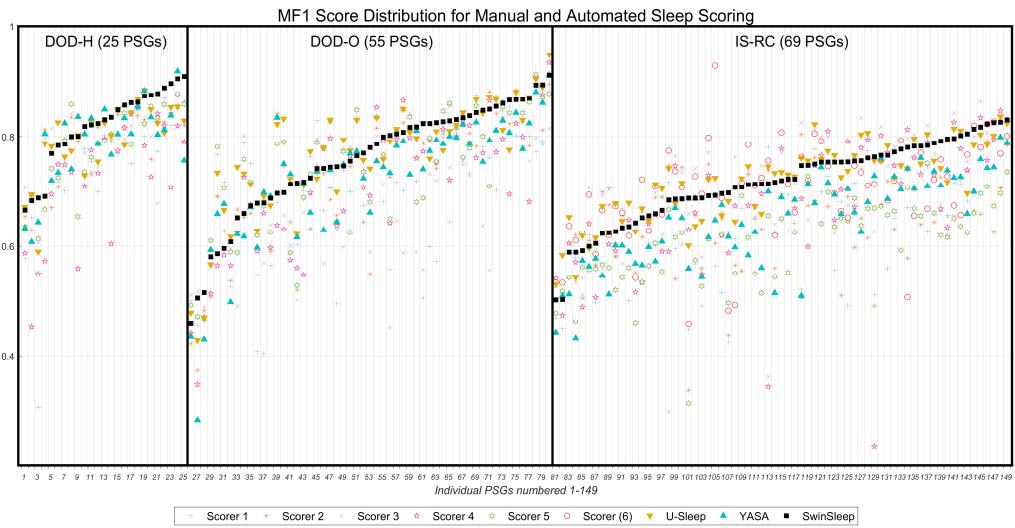


Figure S8. Total sleep time (TST) distribution for manual and automated sleep scoring, tested in the DOD-H, DOD-O and IS-RC cohort.

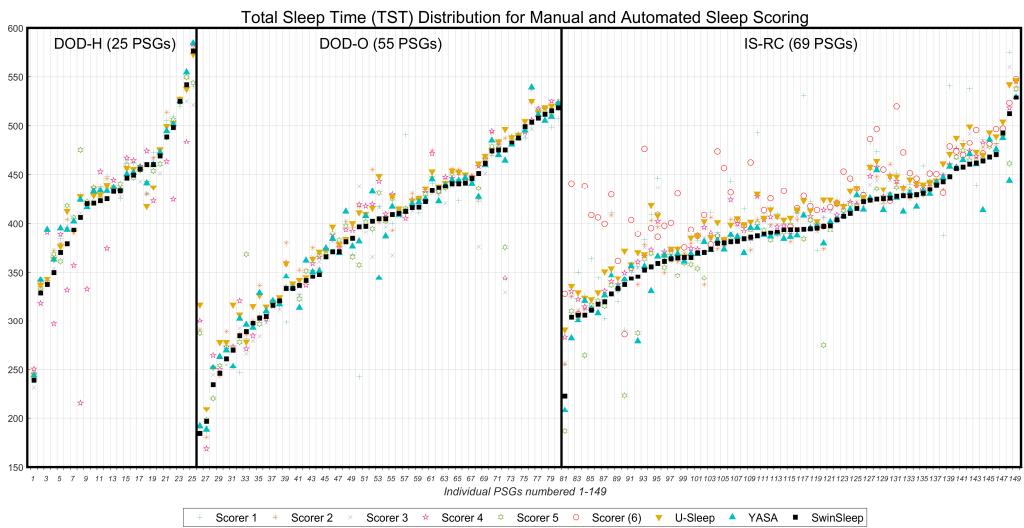


Figure S9. Sleep onset latency (SOL) distribution for manual and automated sleep scoring, tested in the DOD-H, DOD-O and IS-RC cohort.

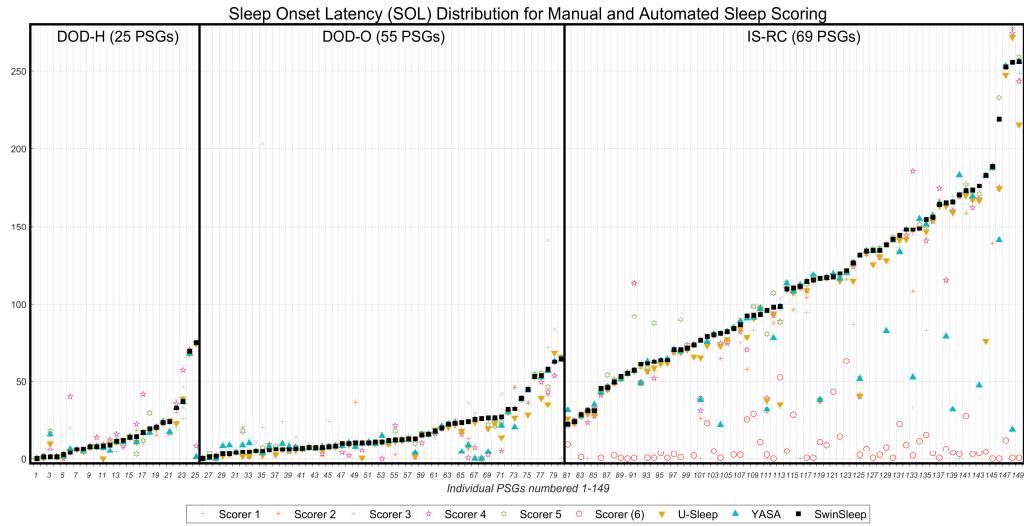


Figure S10. REM onset latency (ROL) distribution for manual and automated sleep scoring, tested in the DOD-H, DOD-O and IS-RC cohort.

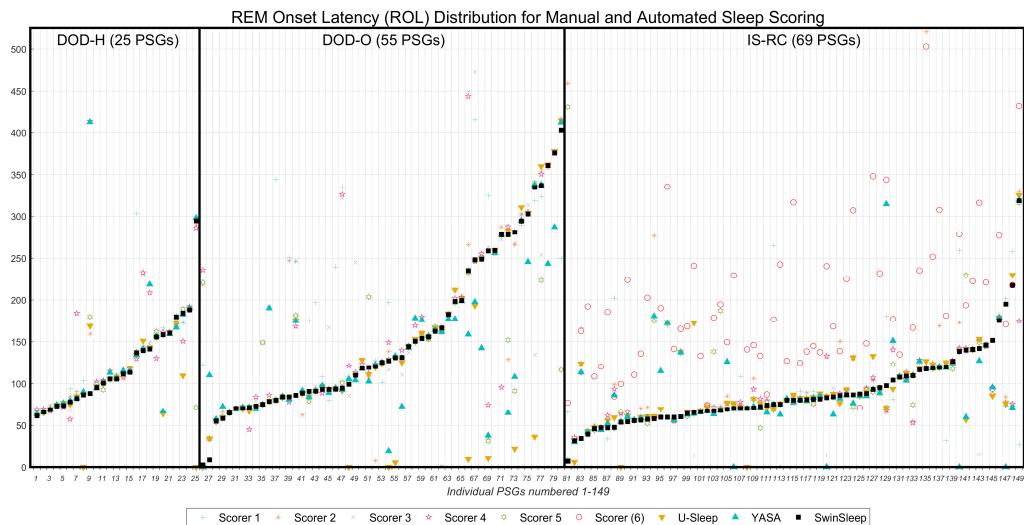


Figure S11. Sleep efficiency (SE) distribution for manual and automated sleep scoring, tested in the DOD-H, DOD-O and IS-RC cohort.

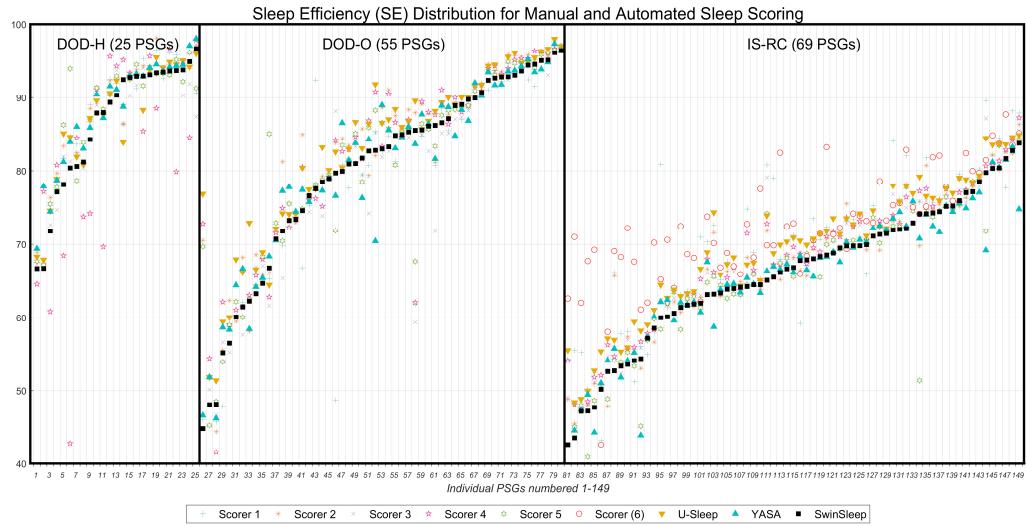


Figure S12. Wake after sleep onset (WASO) distribution for manual and automated sleep scoring, tested in the DOD-H, DOD-O and IS-RC cohort.

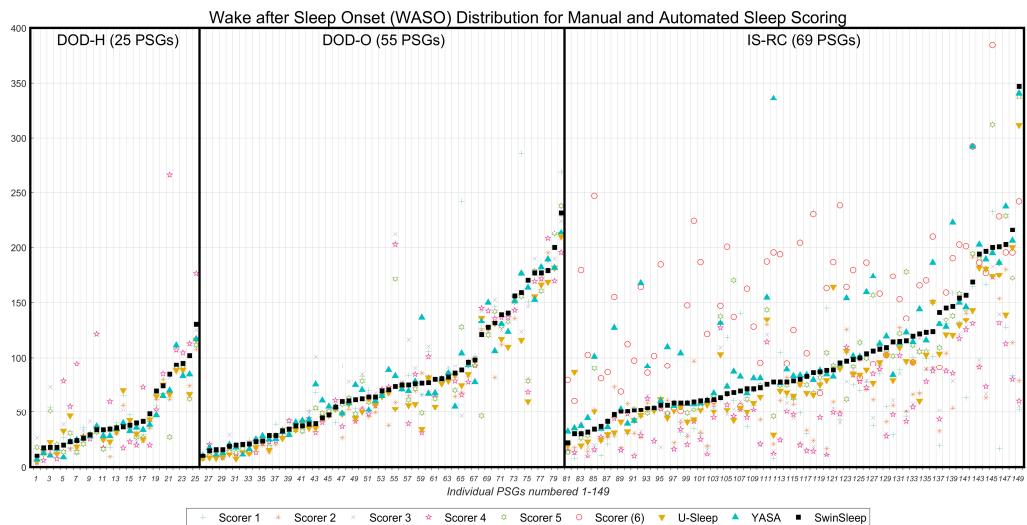


Figure S13. Proportion of N1 in sleep distribution for manual and automated sleep scoring, tested in the DOD-H, DOD-O and IS-RC cohort.

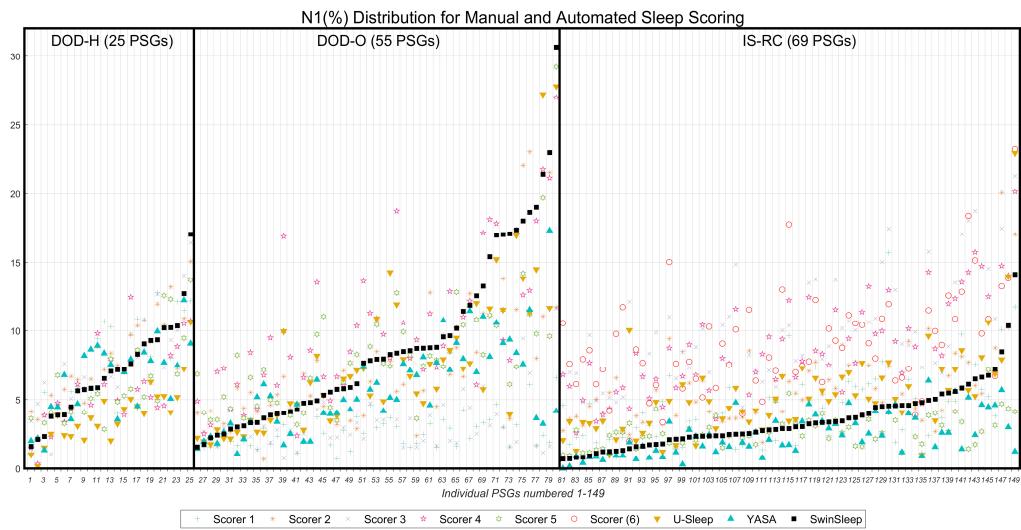


Figure S14. Proportion of N2 in sleep distribution for manual and automated sleep scoring, tested in the DOD-H, DOD-O and IS-RC cohort.

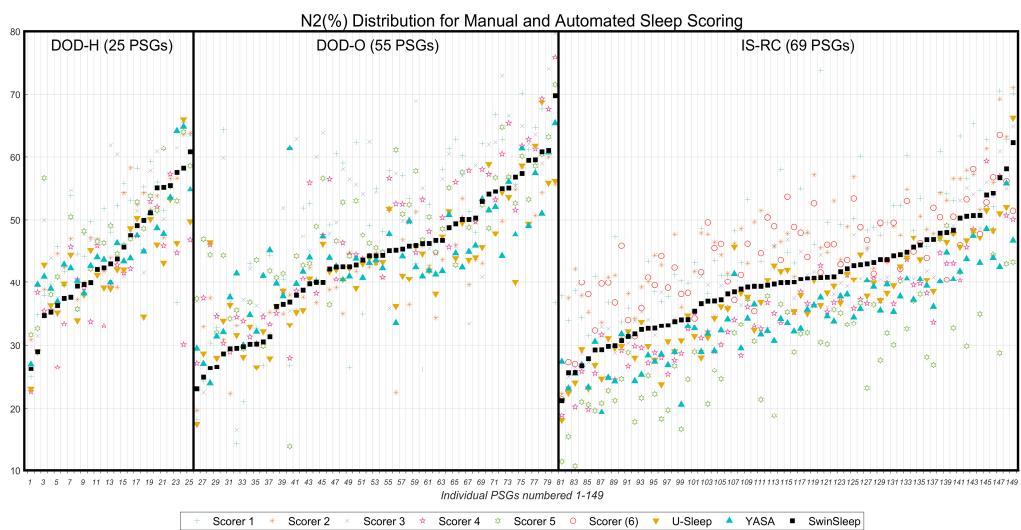


Figure S15. Proportion of N3 in sleep distribution for manual and automated sleep scoring, tested in the DOD-H, DOD-O and IS-RC cohort.

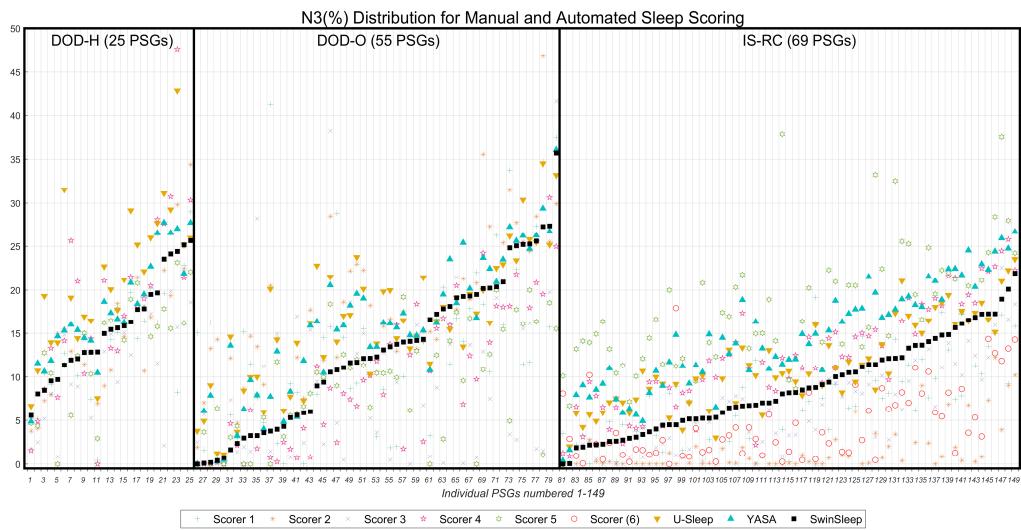


Figure S16. Proportion of REM in sleep distribution for manual and automated sleep scoring, tested in the DOD-H, DOD-O and IS-RC cohort.

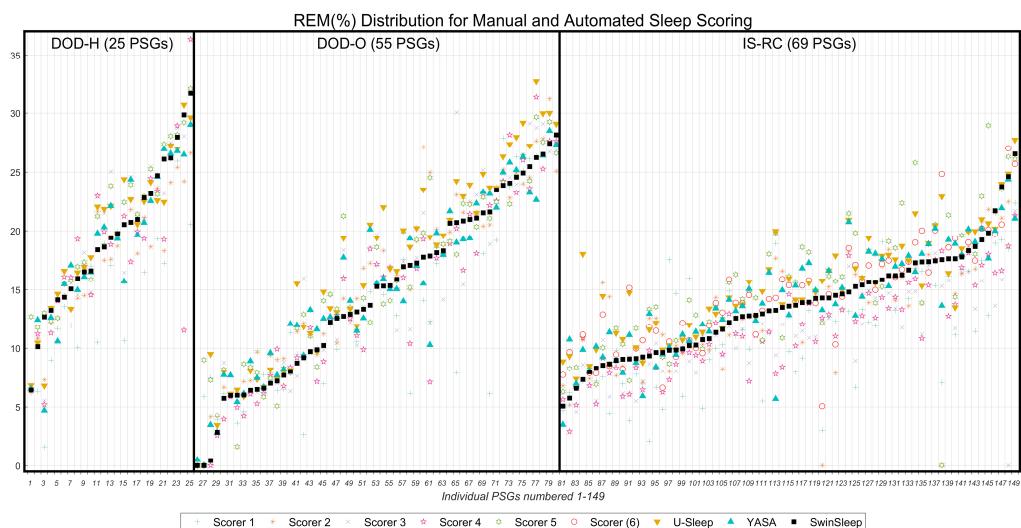


Figure S17. Stage shift index (SSI) distribution for manual and automated sleep scoring, tested in the DOD-H, DOD-O and IS-RC cohort.

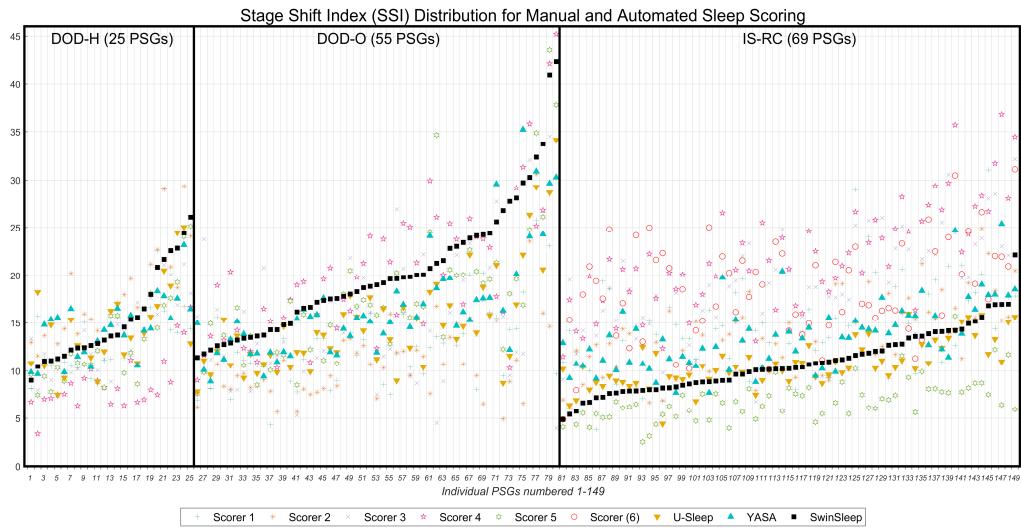


Figure S18. NREM survival indicator (NSI) distribution for manual and automated sleep scoring, tested in the DOD-H, DOD-O and IS-RC cohort.

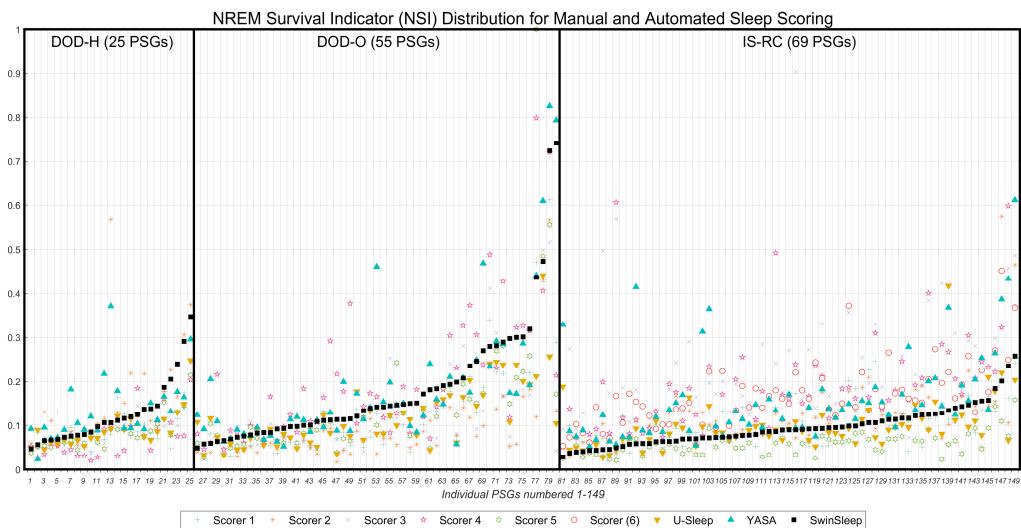
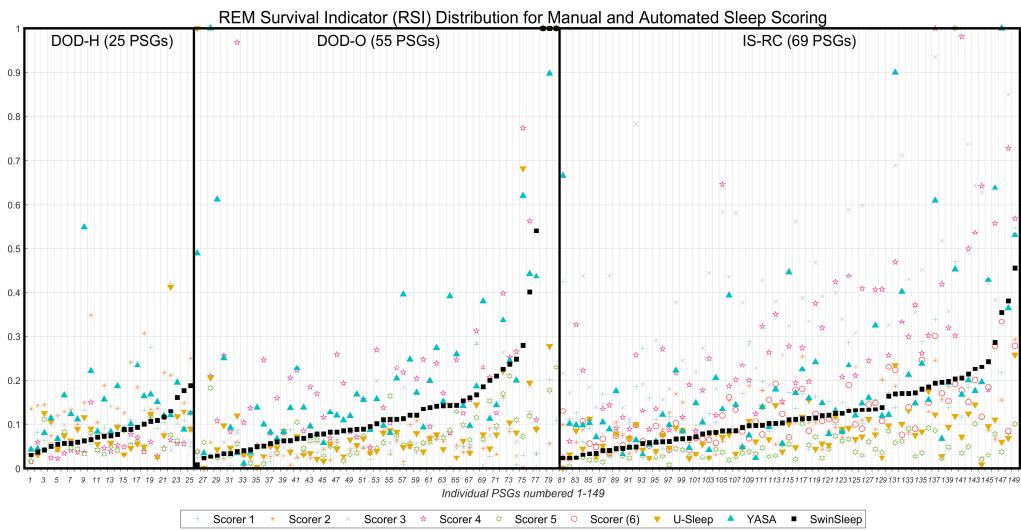


Figure S19. REM survival indicator (RSI) distribution for manual and automated sleep scoring, tested in the DOD-H, DOD-O and IS-RC cohort.



Supplementary Notes

Excluded PSG Labels. The following text enumerates the PSG data labels excluded based on exclusion criteria (2-4).

SHHS1,200068	SHHS1,200094	SHHS1,200147
SHHS1,200202	SHHS1,200228	SHHS1,200245
SHHS1,200251	SHHS1,200384	SHHS1,200401
SHHS1,200410	SHHS1,200468	SHHS1,200668
SHHS1,200707	SHHS1,200787	SHHS1,200815
SHHS1,201017	SHHS1,201199	SHHS1,201234
SHHS1,201263	SHHS1,201277	SHHS1,201279
SHHS1,201284	SHHS1,201325	SHHS1,201343
SHHS1,201353	SHHS1,201377	SHHS1,201392
SHHS1,201425	SHHS1,201438	SHHS1,201472
SHHS1,201494	SHHS1,201499	SHHS1,201511
SHHS1,201521	SHHS1,201530	SHHS1,201554
SHHS1,201632	SHHS1,201644	SHHS1,201647
SHHS1,201678	SHHS1,201803	SHHS1,201852
SHHS1,201928	SHHS1,202001	SHHS1,202002
SHHS1,202008	SHHS1,202055	SHHS1,202088
SHHS1,202089	SHHS1,202146	SHHS1,202148
SHHS1,202193	SHHS1,202280	SHHS1,202311
SHHS1,202328	SHHS1,202348	SHHS1,202366
SHHS1,202371	SHHS1,202393	SHHS1,202405
SHHS1,202494	SHHS1,202495	SHHS1,202498
SHHS1,202503	SHHS1,202518	SHHS1,202527
SHHS1,202553	SHHS1,202558	SHHS1,202559
SHHS1,202573	SHHS1,202578	SHHS1,202609
SHHS1,202622	SHHS1,202623	SHHS1,202626
SHHS1,202633	SHHS1,202647	SHHS1,202695
SHHS1,202717	SHHS1,202745	SHHS1,202826
SHHS1,202832	SHHS1,202835	SHHS1,202849
SHHS1,202890	SHHS1,202899	SHHS1,203001
SHHS1,203089	SHHS1,203115	SHHS1,203139
SHHS1,203432	SHHS1,203567	SHHS1,203571
SHHS1,203574	SHHS1,203645	SHHS1,203647
SHHS1,203680	SHHS1,203715	SHHS1,203766
SHHS1,203829	SHHS1,203837	SHHS1,203883
SHHS1,203977	SHHS1,204054	SHHS1,204211
SHHS1,204241	SHHS1,204278	SHHS1,204513
SHHS1,204917	SHHS1,204930	SHHS1,204945
SHHS1,204956	SHHS1,204973	SHHS1,205005
SHHS1,205029	SHHS1,205030	SHHS1,205052
SHHS1,205199	SHHS1,205235	SHHS1,205243

SHHS1,205252	SHHS1,205287	SHHS1,205449
SHHS1,205535	SHHS1,205557	SHHS1,205768
SHHS2,200562	SHHS2,201028	SHHS2,201058
SHHS2,201093	SHHS2,201224	SHHS2,201280
SHHS2,201323	SHHS2,201343	SHHS2,201503
SHHS2,201507	SHHS2,201547	SHHS2,201843
SHHS2,201969	SHHS2,202135	SHHS2,202183
SHHS2,202592	SHHS2,202602	SHHS2,203193
SHHS2,203348	SHHS2,203383	SHHS2,203395
SHHS2,203469	SHHS2,203520	SHHS2,204404
SHHS2,204407	SHHS2,204444	SHHS2,205105
SHHS2,205355	SHHS2,205625	SHHS2,205688
SOF,03439	SOF,06671	SOF,10271
SOF,10514	CFS,800272	CFS,800380
CFS,800393	CFS,801001	CFS,801432
CFS,801549	CFS,801805	CFS,802299
MROS1,aa0265	MROS1,aa0275	MROS1,aa0559
MROS1,aa0598	MROS1,aa0722	MROS1,aa0965
MROS1,aa1324	MROS1,aa1346	MROS1,aa1999
MROS1,aa2268	MROS1,aa2602	MROS1,aa2718
MROS1,aa2756	MROS1,aa3083	MROS1,aa3452
MROS1,aa4156	MROS1,aa4329	MROS1,aa4468
MROS1,aa4572	MROS1,aa4668	MROS1,aa4690
MROS1,aa4719	MROS1,aa5657	MROS1,aa5669
MROS1,aa5688	MROS1,aa5833	MROS1,aa5935
MROS2,aa0085	MROS2,aa0208	MROS2,aa0675
MROS2,aa0821	MROS2,aa1346	MROS2,aa1361
MROS2,aa1471	MROS2,aa1613	MROS2,aa2060
MROS2,aa2528	MROS2,aa2571	MROS2,aa3175
MROS2,aa3220	MROS2,aa3556	MROS2,aa4000
MROS2,aa4221	MROS2,aa4731	MROS2,aa5657
MESA,0590	MESA,0989	MESA,1118
MESA,1641	MESA,1659	MESA,1691
MESA,1758	MESA,1891	MESA,1982
MESA,2067	MESA,2208	MESA,2292
MESA,2537	MESA,2668	MESA,3073
MESA,3150	MESA,3931	MESA,4443
MESA,5623	MESA,6043	MESA,6746
HPAP1,1600017	HPAP2,1600251	NCHSDB,15664_19573.tsv
NCHSDB,16933_26176.tsv	NCHSDB,1885_21658.tsv	NCHSDB,4405_7198.tsv
NCHSDB,9559_12535.tsv	CNC,chp025	PHY,0023
DHC,Sub93	93	